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No. 1

OWNERSHIP AND OPERATION OF TRENCH EXCAVATORS AND OTHER MECHANICAL EQUIPMENT BY THE WATER DEPARTMENT OF BALTIMORE¹

By V. BERNARD SIEMS²

HISTORICAL INFORMATION REGARDING THE USE OF MACHINERY BY THE BALTIMORE CITY WATER DEPARTMENT

Machinery for excavating earth and other material has been recognized for years as more economical and efficient than manual methods where conditions will permit the use of such mechanical equipment.

In order to complete the construction of water supply and sewerage systems in the cantonments during the world war as quickly as possible, the United States Army used machinery entirely, and the results obtained have, no doubt, had a great effect on the increased use of trench excavators, cranes and backfillers by contractors and municipalities. The writer used trenching machines, cranes and backfillers entirely for the construction of the water distribution system for Camp Meade and Camp Franklin in 1918. The distribution system of Camp Franklin and the enlargement of the Camp Meade system were completed in 2½ months. Machinery of all characters was used to construct the intake and pumping stations and to enlarge the filtration plant and balancing reservoirs at Camp Meade.

¹ Presented before the Cleveland Convention, June 7, 1921.

² Principal Assistant Engineer, Water Department, Baltimore, Maryland.

In 1913 the engineers of the Baltimore City Water Department saw the necessity for obtaining a trenching machine, air compressor and pneumatic hammer to execute more expeditiously the work in connection with the installation of water mains. The Highways Department, in 1913, graded 33rd Street from Greenmount Avenue to Hillen Road, an approximate distance of 1.1 miles, preparatory to constructing a boulevard. The Water Department started the work of installing a 16-inch middle service water main by hand labor. As the cost of doing the work was exceeding the estimated



FIG. 1

amount appropriated, the Department engineers rented a trenching machine from the Consolidated Gas Company. With the use of this machine the work was rapidly pushed to completion and the cost was less than the amount actually appropriated. This rented machine excavated 2000 linear feet of trench, and the final cost showed that the excavating had been done at 16 cents a cubic yard. Based on this excellent showing, the Water Department was permitted to purchase a "Parsons" trench excavator, Model "K." Another important reason for permitting the purchase of a trenching

machine was that the greater part of future water mains installations would be in the northeastern and northwestern sections of the city where few, if any, subsurface structures would be encountered, and conditions would be ideal for operating trenching machines. The normal corps of fifteen laborers was too small to permit constant operation of the trenching machine in the work of laying water mains and backfilling, and it was necessary to increase the number of men. In order to increase the amount of work even more and bring the water mains construction corps to the normal size of fifteen laborers, air



FIG. 2

compressors and pneumatic hammers were procured. This latter equipment was also necessary to secure uniform caulking of all pipe joints and, thereby, to decrease the probability of leaks occurring after the laying of improved paving. It also reduced the time, and consequently the cost of labor, in caulking.

The first air compressor purchased was of "Foster & Hosler" make and had a capacity of approximately 80 cubic feet. Considerable difficulty was experienced in training the caulkers to use the pneumatic hammers intelligently in order to prevent breaking the bells

of cast iron pipe. Tests conducted over a long period showed that pneumatic hammers should operate under a long stroke and at a moderate working pressure of 40 pounds per square inch. The Engineering and Construction Division of the Water Department now has the following equipment:

<i>Equipment</i>	<i>Original cost</i>
4 Air compressors (ranging from 80 to 210 cubic feet capacity).....	\$8,189.00
2 Backfillers.....	3,488.00
1 Austin 5-ton crane.....	8,095.00
1 Ransome concrete mixer.....	802.00
1 Air piling hammer.....	275.00
10 Ditch pumps.....	3,447.00
3 Trenching machines.....	23,794.00
Total.....	\$48,090.00

From table 1 it is particularly noticeable that most of the machinery was purchased by the Water Department between the years 1918 and 1920. This chart also shows the total equipment of the larger types of machinery now used by the Water Department. Since the year 1914 the Water Department has used trenching machines under almost all conditions in the installation of water mains in public highways. The "Parsons" Model "K" trenching machine was put to a severe test at one time in excavating for the installation of a 4-inch water main in a private alley between 10 and 12 feet in width. Difficulty was experienced in getting a trenching machine of this size in the alley, and damage was done to the wooden fences on each side of the alley. Even considering the difficulties and the expense entailed because of the damage done, the cost of installing the 4-inch main was much less than it would have been if done by manual labor. It may be interesting to note that a comparison of the cost of doing work in private alleys of various widths and public highways, whether done by manual labor or by trenching machine aided by hand labor, shows that the cost of the installation in private alleys is twice that of the cost in public highways. The Water Department, therefore, does not even consider the installation of water mains in private alleys. Judging from our records of cost, such installations should be discouraged by all municipalities.

Trenching machines have also been used to remove the cover of all sizes water mains where it has been found necessary to enlarge or

replace them by other mains, particularly in cases where it is necessary to lower the water mains because of a change in the grade of the public highway. In the residential and business districts where it would be economical to excavate trenches with trenching machines for installation of water mains, accurate locations were obtained of water, gas and other services in advance of the work. The locations of these services were marked on the curb line, and the trenching machine operator very seldom disturbed any of them, as he raised the boom of the machine as it approached these marks. It was, of course, necessary to do the extra excavating around the service pipes by hand labor. In other instances the Department has found it economical to disconnect these services temporarily, in order to provide clearance for the operation of the trenching machine. Even with these additional costs, there was considerable economy in the use of the trenching machine, especially on the installation of large water mains. From our cost data records, it is estimated that damages to subsurface structures by the use of trenching machine approximate 1 per cent of the total cost of the installation of the water mains.

In 1918, due to the increasing number of extensions of water mains, the scarcity of labor and the high rate of pay necessary because of the salaries paid labor by industrial plants in and around Baltimore, it was decided to purchase additional trenching machines, a 5-ton "Austin" crane and backfillers. The cost of installing water mains was materially lessened by the use of this machinery in years 1919 and 1920. The 5-ton crane saved us considerable money, as we handled practically all cast iron water pipe and fittings of 20 inches and over with it. Two types of backfillers are used—one the boom drag and the other the scraper drag. The boom drag is used on the backfilling of trenches for large mains and the scraper drag on smaller mains in territories where the Highways Department will permit backfilling of ditches by puddling the material. We have, however, also used it in public highways where ramming was necessary. Tests made with mechanical tampers have not shown satisfactory results thus far. It is hoped that they will be developed to the extent of the other machinery now used by the Water Department. We have a much larger equipment of machinery than that noted on Table 1 in machines of a smaller character which we purchased from time to time and which are not shown on the table. I believe that the Water Department of the City of Baltimore ranks

TABLE 1
Method of ascertaining the cost per hour of operating machines

(1) TYPE OF MACHINE	(2) DESIGNATED AS	(3) ORIGINAL COST	(4) PROBABLE LIFE	(5) DATE OF DELIVERY	(6) PROBABLE NO. OF HOURS IN OPERATION	(7) DEPRECIATION COST PER HOUR	(8) FUEL CONSUMED PER HOUR	(9) PROBABLE REPAIR COST PER HOUR	(10) TOTAL COST PER HOUR	(11) OPERATOR'S COST PER HOUR	(12) TOTAL OPERATING COST PER HOUR
			years								
Air compressors											
Ingersoll-Rand.....	A. C. No. 1	\$3,058	5	November 1920	2,000	\$0.31	\$0.61	\$0.08	\$1.00	\$1.00	\$2.00
Sullivan.....	A. C. No. 2	2,531	5	December 1920	2,000	0.25	0.61	0.09	0.95	1.00	1.95
2 Foster & Hosler.....	A. C. Nos. 3 and 4	1,300	5	March 1918	2,000	0.13	0.15	0.02	0.30	1.00	1.30
Backfillers:											
Backfiller M. 5.....	B. No. 1	847	5	October 1918	800	0.21	0.11	0.10	0.42	1.00	1.42
Backfiller M. 10.....	B. No. 2	2,641	5	October 1920	800	0.66	0.37	0.10	1.13	1.00	2.13
Crane:											
Austin.....	C. No. 1	8,095	5	August 1919	1,000	1.62	0.96	0.20	2.78	1.00	3.78
Concrete mixer:											
Ransome.....	C. M. No. 1	802	5	October 1920	800	1.00	0.23	0.02	1.25	1.00	2.25
Hammer:											
Air piling.....	A. H. No. 1	275	5	March 1920	250	0.22		0.03	0.25	1.00	1.25
Pumps:											
3—Novo 4 H. P.....	P. No. 1	390	3	March 1919	2,000	0.07	0.19	0.04	0.30	1.00	1.30
3—Novo 2½ H. P.....	P. No. 2	349	3	April 1919	2,000	0.06	0.19	0.04	0.29	1.00	1.29
1—Novo Centrifugal.....	P. No. 3	490	3	February 1919	2,000	0.08	0.19	0.04	0.31	1.00	1.31
1—Domestic.....	P. No. 4	180	3	February 1919	2,000	0.03	0.19	0.03	0.25	1.00	1.25
2—Schramm.....	P. No. 5	280	3	February 1919	2,000	0.05	0.19	0.04	0.28	1.00	1.28

Trenching machines:		T. M. No. 1		5		April		1914		1,456		1.39		0.31		1.70		1.00		2.70	
Parsons Model K.....		T. M. No. 2		5		December		1920		1,456		0.63		0.25		2.00		1.00		3.00	
Parsons Model 24.....		T. M. No. 3		5		April		1920		1,456		1.40		0.25		3.04		1.00		4.04	
Parsons Model 36.....																					

Columns 1, 2, 3, 4, 5, 6, 10, 11 and 12 are self-explanatory. Column 7—Column 3 divided by column 4 equals depreciation cost per year and this quotient divided by column 6 equals depreciation cost per hour. Column 8—Fuel consumed per hour ascertained by test on each machine and is approximately as follows: 90 per cent gasoline, 3 per cent grease and 7 per cent lubricating oil. Column 9—Yearly cost of repairs for each machine divided by column 6 equals repair cost per hour.

first among American municipalities in the use of machinery for doing the work in connection with the installation and maintenance of a water distribution system.

ORGANIZATION FOR OPERATING AND REPAIRING MECHANICAL EQUIPMENT

Figure 3 shows the organization of the operating and repair corps of mechanical equipment used by the Construction Subdivision of the Engineering and Construction Division. The automobile repairman, grade 1, in charge of mechanical equipment reports directly to the Assistant Civil Engineer in charge of the Construction Sub-

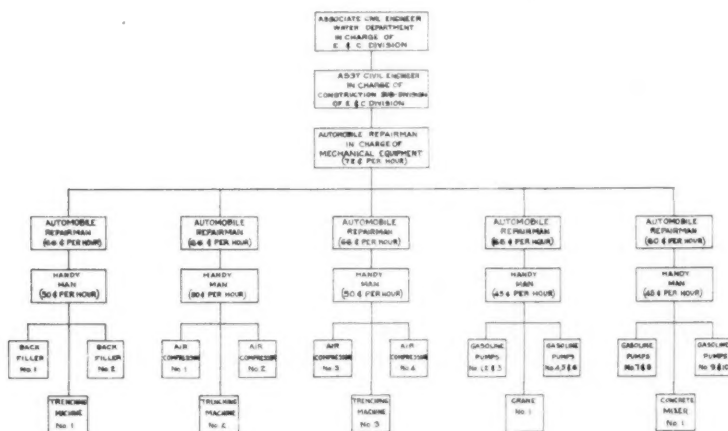


FIG. 3

division or his assistant, the same as the water pipe construction foremen do. The five automobile repairmen, grades 2 and 3, are subordinates assisted by handy-men. To each group equipment which they operate and maintain, is assigned.

The City Service Commission of Baltimore requires that an automobile repairman must have an elementary education, several years' experience in assembling or repairing and operating gas engines and other mechanical equipment. For handy-men it requires an elementary education, one year's experience as general handy-man in a machine shop and ability to follow instructions from an automobile repairman. The handy-men are also used for burning out lead cast iron pipe bells on mains of the larger size. From ex-

perience it has been found that the best men available for positions of automobile repairmen are those advanced from the position of handy-man.

Experience in the use of mechanical equipment has proved to us that it is more economical and efficient to have a storage of duplicate mechanical parts available for any emergency than to order the repair parts when needed. The automobile repairman, grade 1, in charge of mechanical equipment is held responsible for stock parts of mechanical equipment and also for repairs to machinery. After the completion of the work the machinery is inspected thoroughly before being transported to another location, and, therefore, it is always in good working condition to commence the next work.

During winter months trenching machines, cranes, backfillers, air compressors, etc. are removed to the storage yards and completely overhauled. This is done only when there is no work on which this machinery can be used. The smaller gasoline pumps, melting furnaces, ground thawers, etc. are usually overhauled in the field.

COMPARISON OF COSTS—HAND LABOR VERSUS HAND LABOR AIDED BY MACHINERY

Curve 1 of figure 4 shows the comparison of labor cost per foot of installation of water mains by manual labor and manual labor aided by trenching machine. Referring to the table accompanying this curve, it will be seen that the percentage of economy obtained using a trenching machine with hand labor varies from 22.2 to 57.4 per cent. This percentage of saving is largely due to the intelligent placing of the laborers. For example with an average corps of fourteen men working with a trenching machine in the installation of a 6-inch water main, two laborers work on the surface to remove the material falling from the traveling buckets, three laborers are used to prepare the trench for pipe laying, two caulkers and two laborers pour the lead and caulk the joints, four laborers backfill the trench and ram the material, and one laborer attends to the lead melting furnace and keeps the water main installation corps supplied with tools. Such an organization will permit constant operation of a trenching machine throughout the working day.

The labor costs shown on curve 1 are average ones which include excavating and backfilling of trench, installation of the cast iron

pipe and the overhead of the watchman and foreman. The standard dimensions of trench used by the Department are shown below curve 1. From experience we have found that four feet of cover will prevent freezing and the pipe will not be affected by vibration caused by heavy motor vehicles.

Curve 2 of figure 4 shows the comparison of excavation cost per foot of installation of water main by manual labor and trenching machine aided by manual labor. The percentage of saving with the use of the trenching machine varies from 50 to 56.8 per cent. A trenching machine will excavate from 15 cubic yards an hour in

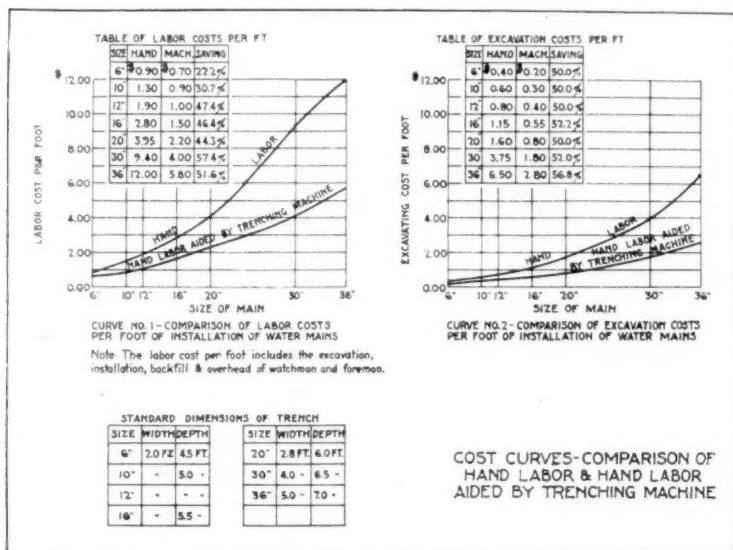


FIG. 4

50 per cent rock and sandstone to 25 cubic yards an hour in loam, gravel and disintegrated rock.

Curve 3 of figure 5 shows the comparison of average number of feet of water main installed by a man a day by hand labor and by hand labor aided by trenching machine. The term "installed" includes the excavation for, installation and backfill of the water main. This curve shows the saving of time in the installation of water mains by the use of the trenching machine. Referring to the table above the curve you will see that the percentage of time saved varies from 33.3 to 80.0 per cent. For example, it will take a water

pipe corps of fifteen men installing water mains without the use of a trenching machine ten days to excavate for, lay and backfill 300 feet of 20-inch main, whereas a pipe laying corps using a trenching machine to excavate the trench will complete the excavation, laying and backfilling of the 20-inch main in four days and two hours. Below this curve is a table of the standard dimensions of trench.

Curve 4 of figure 5 shows the average number of men the trenching machine replaces. This curve depicts the trenching machine as a labor saving device. Upon examining the curve and the table, you

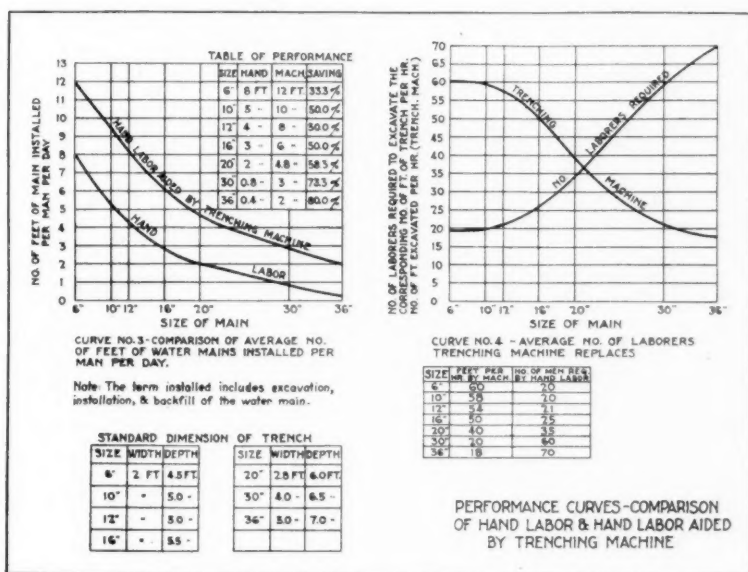


FIG. 5

will find that the number of men replaced by the use of the trenching machine varies from 20 to 70 men. For an example, take a 6-inch main: The number of linear feet of trench excavated in one hour by the trenching machine is 60, but it would require 20 men to excavate the 60 feet of trench in one hour. The same principle applies to the other size mains, the table giving the number of men replaced by the trenching machine for water mains of every size. This curve and table were prepared from the average of a number of installations of water mains of each size noted upon the slide.

Curve 5 of figure 6 shows comparison of labor costs per foot of water mains between joints caulked by hand and those caulked with the use of pneumatic tools. The term "laying" refers only to the placing of the pipe in the trench and to the caulking of the joints. In the table of comparison of cost of caulking by hand and caulking with air hammers, you will notice that there is a loss varying from 37 to 53 per cent in favor of hand caulking but this loss is overcome by the saving in time varying from 41.7 to 65.7 per cent by caulking with air hammers, thus resulting in a saving of 36.4 to 46.7 per cent on the completed work.

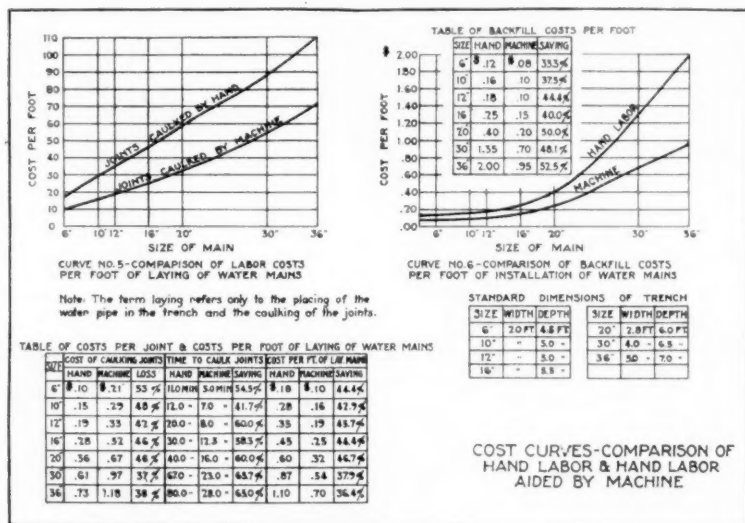


Fig. 6

Curve 6 of figure 6 shows the comparison of backfill costs per foot of installation of water mains by hand labor and by backfiller. From the curve and tables you will find that the percentage of saving varies from 33.3 to 52.5 per cent. Below the curve is a table of the standard dimensions of trench.

In order to determine the effective depth to which lead could be compressed in the caulking of cast iron water pipe joints, research work was initiated at the Municipal Laboratory in 1914. The results of these tests showed that lead, like other engineering materials, has a distinctly characteristic curve. From this curve may be

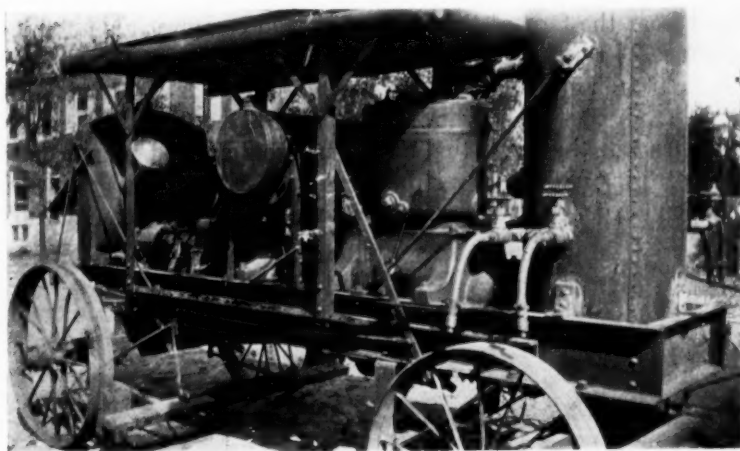


FIG. 7



FIG. 8

found the greatest possible compression, which never exceeds $2\frac{1}{2}$ inches from the face of the bell, before the compressive molecular resistance of the lead itself equals or is greater than the strength of the cast iron in the sides of the pipe bells. When the latter is the case, there immediately follows a bursting of the pipe bell. It was recommended, therefore, that air compressors and pneumatic hammers operating under a long stroke and a moderate working pressure of 40 pounds per square inch be used on all the Department's caulking work.



FIG. 9

A comparison of cost of the laying of water mains by hand labor and hand labor aided by crane on pipe 30 inches and larger shows that it cost \$0.54 a foot to lay 30-inch pipe with hand labor aided by crane, and \$0.95 a foot to lay by hand labor alone, or a saving of 43.1 per cent by using the crane. On 36-inch pipe it cost \$0.70 a foot to lay with hand labor aided by crane, and \$1.42 to lay with hand labor alone, or a saving of 50.7 per cent.

Table 1 shows the method of ascertaining the cost per hour of operating machinery. The explanation is given in the notes at bottom of the table.

Table 2 shows cost per foot of installation of water mains during part of years 1920 and 1921 by hand labor and by hand labor aided by trenching machine. The labor costs per foot (column 2) shown in this table include the cost of inserting small connections such as 6, 10 or 12 inch and the installation of 6, 10 and 12 inch valves at an average distance of 400 feet which constitutes the length of a city block. The same applies to the material cost per foot of installation of 6, 10 and 12 inch water mains (column 4). The columns are explained by the notes at the bottom of the table.

Table 3 shows the hourly rate of pay and water works material cost. An explanation is given in the notes at bottom of the table.

Table 4 shows methods of ascertaining depreciation charges on standard tools and equipment of water pipe construction foreman. These computations are the result of investigation of field conditions and are not assumptions. The depreciation charges are based upon a year of 300 working days.

Table 5 shows the methods of ascertaining the percentage of labor cost per foot of water mains installations covering loss and depreciation of tools. These results are explained by the notes.

Table 6 shows the method of ascertaining the overhead charge against each construction order. The Water Department consists primarily of the Engineering and Construction Division, Mechanical Division and Filtration Division. The Executive and Auditing Divisions are not considered separate as their entire operating cost is divided among the three above-mentioned divisions. The Construction Subdivision being one of three subdivisions of the Engineering and Construction Division, 11.11 per cent of the salaries of the Executive and Auditing Divisions of the Water Department, 33.33 per cent of the salaries of the executive and clerical forces of the Engineering and Construction Division, 100 per cent of the salaries of the engineers and clerks of the Construction Subdivision, the expenditure of the Bureau of Drafting for preparing Water Department plans and 11.11 per cent of the miscellaneous appropriations (buildings, equipment, automobiles, instruments, stationery, etc.) are charged to the Construction Subdivision as overhead. Dividing the total sum obtained as overhead by the total estimated expenditure of the Construction Subdivision, the percentage of overhead is obtained.

Table 7 shows the cost per foot of installation of water supply services, valves and fire hydrants, also standard dimensions of valve

30	12.35	0.80	15.30	1.24	2.97	32.66	9.00	0.80	15.30	0.90	2.60	28.60	Maximum
30	9.40	0.80	15.30	0.94	2.64	29.08	4.00	0.80	15.30	0.40	2.05	22.55	Average
30	5.20	0.80	15.30	0.52	2.18	24.00	3.40	0.80	15.30	0.34	1.98	21.82	Minimum
36	16.85	0.95	19.20	1.69	3.87	42.56	12.20	0.95	19.20	1.22	3.36	36.93	Maximum
36	12.00	0.95	19.20	1.20	3.34	36.69	5.80	0.95	19.20	0.58	2.65	29.18	Average
36	9.85	0.95	19.20	0.99	3.10	34.09	5.10	0.95	19.20	0.51	2.58	28.34	Minimum

Columns: 1—Water mains and fittings. 2—Excavating, laying, backfilling; overhead of foremen and watchmen. 3—Hauling pipe, fittings, etc.; investigating subsurface obstructions; operating valves. 4—Cost of cast iron pipe fittings, rope, timbers, etc. 5—10 per cent of labor cost (see chart 9). 6—10 per cent of summary of columns 2, 3, 4 and 5. 7—Total cost of installation. 8—Material excavated and subsurface obstructions encountered. *Maximum*—(a) Material excavated—50 per cent sandstone, granite or other rock, or (b) subsurface obstructions of such a nature that (a) would apply as to time and cost of work (industrial sections). *Average*—(a) Material excavated—loam, clay, gravel and deteriorated rock, or (b) subsurface obstructions of such a nature that (a) would apply as to time and cost of work (industrial and business sections). *Minimum*—(a) Material excavated—sand, loam and gravel, or (b) subsurface obstructions of such nature as found in typical residential public highways.

TABLE 3
Hourly rate of pay and water works material costs

HOURLY RATE OF PAY				MATERIAL COSTS			
Title	Maximum	Average	Minimum	Material	Unit price	Material	Unit price
Water pipe construction foreman	\$0.72	\$0.63	\$0.56	Class B cast iron pipe	\$71.00 per ton	$\frac{3}{4}$ -inch wrought iron lead lined pipe	\$0.22 per foot
Labor foreman	.54	.54	.54	Cast iron fittings	140.00 per ton	1-inch wrought iron lead lined pipe	.30 per foot
Handy man	.55	.525	.50	Coal oil	.115 per gallon	2-inch wrought iron lead lined pipe	.70 per foot
Pipe caulker	.50	.50	.50	Gasoline	.235 per gallon	$\frac{3}{4}$ -inch corporation	1.34
Special laborer	.45	.425	.40	Lead	.055 per pound	1-inch corporation	1.45
Night watchman	.38	.38	.38	Lumber	.045 board foot	2-inch corporation	7.84
				Packing rope	.09 per pound	3-foot curb stop box	1.58
						5-foot curb stop box	1.95

Note: \$71.00 per ton for class "B" cast iron pipe refers to unit purchase price in year 1920. Present unit price for class "B" cast iron pipe is \$61.00 per ton. Other unit prices refer to purchases made in 1921.

TABLE 4

*Method of ascertaining depreciation charges on standard tools equipment
of a water pipe construction foreman—construction sub-division*

DESCRIPTION OF A WATER PIPE CONSTRUCTION FOREMAN'S EQUIPMENT FOR AN AVERAGE SIZE CORPS OF 14 MEN	PROBABLE LIFE OF EQUIPMENT	ORIGINAL COST OF EQUIP- MENT	DEPRECI- ATION COST PER DAY OF EQUIP- MENT
1 Watchman's house.....	5 years	\$255.00	\$0.17
1 First-aid cabinet (complete).....	3 months	15.00	0.20
1 Oil stove.....	1 year	6.00	0.02
2 Tool boxes.....	2 years	50.00	0.08
15 Picks.....	6 months	17.00	0.11
15 Long-handle shovels.....	6 months	39.75	0.26
4 Mattocks.....	6 months	8.00	0.05
2 Digging bars.....	6 months	6.80	0.05
2 Steel bars.....	6 months	7.60	0.05
6 Wall points.....	3 months	12.00	0.16
10 Ditch jacks.....	1 year	50.00	0.17
4 Sledge hammers.....	3 months	8.00	0.10
4 4½ pound hammers.....	3 months	5.00	0.07
1 Adz.....	6 months	2.00	0.01
1 Axe.....	6 months	2.00	0.01
4 Gallous keys.....	1 year	12.40	0.04
2 Socket keys.....	1 year	6.00	0.02
4 Hydrant keys.....	1 year	6.32	0.02
2 N. S. hydrant keys.....	1 year	3.00	0.01
2 Corporation keys.....	1 year	4.50	0.02
2 Curb stop keys.....	1 year	2.00	0.01
12 Handle diamond point tools.....	3 months	12.10	0.16
6 Finger diamond point tools.....	3 months	9.00	0.12
5 Pipe cutters (handle).....	3 months	6.25	0.08
6 Pipe cutters.....	3 months	10.50	0.14
5 Breaking-out chisels.....	3 months	7.50	0.10
3 Long chisels.....	3 months	4.80	0.07
10 Roping tools.....	9 months	11.00	0.05
3 Lead runners.....	6 months	45.00	0.30
1 Hauck lead melting furnace.....	2 years	88.35	0.15
3 9-inch ladles.....	1 year	9.00	0.03
1 6-inch ladle.....	1 year	2.00	0.01
12 Handle caulking tools.....	3 months	12.00	0.16
3 Sets finger caulking tools.....	6 months	36.00	0.24
1 ¼-inch Mueller tapping machine.....	1 year	180.00	0.60
3 Saddles.....	1 year	9.00	0.03
1 Vise.....	1 year	5.50	0.02
2 Three-wheel pipe cutters.....	9 months	24.00	0.12
1 Set stocks and dies.....	6 months	15.00	0.10

TABLE 4—*Concluded*

DESCRIPTION OF A WATER PIPE CONSTRUCTION FOREMAN'S EQUIPMENT FOR AN AVERAGE SIZE CORPS OF 14 MEN	PROBABLE LIFE OF EQUIPMENT	ORIGINAL COST OF EQUIPMENT	DEPRECIATION COST PER DAY OF EQUIPMENT
1 Ditch ratchet (complete).....	1 year	\$25.00	\$0.08
3 Monkey wrenches.....	1 year	8.00	0.03
4 Stillson wrenches.....	1 year	11.32	0.04
2 Rasps.....	6 months	2.50	0.02
1 Oiler.....	2 years	2.50	0.01
3 Rammers.....	2 years	7.00	0.01
1 Wood chisel.....	1 year	5.80	0.02
1 8-inch single block.....	6 months	3.40	0.02
1 8-inch double block.....	6 months	6.00	0.04
1 Hand saw.....	6 months	2.50	0.02
1 Cross-cut saw.....	6 months	8.35	0.06
1 Chain.....	6 months	2.40	0.02
1 Street broom.....	1 year	1.00	0.01
3 Buckets.....	3 months	1.95	0.02
10 Pairs rubber boots.....	6 months	50.00	0.33
15 Slickers.....	1 year	75.00	0.25
15 Standards.....	1 year	30.15	0.10
1 50-foot tape.....	6 months	3.00	0.02
10 Red flags.....	3 months	5.00	0.07
Total.....			\$5.29

From the life and original cost the depreciation for each water pipe construction foreman's equipment is \$5.29 per day.

Note: Method of ascertaining the percentage of labor cost to apply to installation of water mains to cover the depreciation and loss of tools is shown on chart 9.

vaults. The costs per foot of installation of water supply services include tapping the main, insertion of the corporation, lead tail, lead lined pipe, curb stop and curb stop box. The installation of cast iron water supply services includes the insertion of the sleeve and three-way, cast iron pipe, valve and roadway box. The cost of installation of valves includes the cost of the valve, lead, blocking, packing, rope, etc. The cost of erection of the vault for valve includes the labor, material, depreciation and overhead. The cost of the installation of fire hydrants includes the cost of the insertion of three-way and sleeve, cast iron pipe, valve and fire hydrant.

TABLE 5

Method of ascertaining per cent labor cost per foot water mains installed covering loss and depreciation of tools.

SIZE	NUMBER OF MEN IN WATER PIPE CONSTRUCTION CORPS	NUMBER OF FEET WATER MAIN INSTALLED BY CORPS PER DAY	DEPRECIATION COST OF TOOLS PER FOOT OF WATER MAINS INSTALLED		AVERAGE COST PER FOOT OF WATER MAINS COVERING LOSS AND BREAKAGE OF TOOLS	LABOR COST PER FOOT OF WATER MAINS INSTALLED	PERCENTAGE OF LABOR COST PER FOOT OF WATER MAINS INSTALLATION APPLIED TO DEPRECIATION AND LOSS OF TOOLS	
(1)	(2)	(3)	(4a)	(4b)	(5)	(6)	(7a)	(7b)
inches								per cent
6	14	75	\$5.29 75	\$.07	\$0.02	\$0.90	\$.09 .90	10.0
10	14	60	5.29 60	.09	0.03	1.30	.12 1.30	9.2
16	14	30	5.29 30	.18	0.04	2.80	.22 2.80	7.9
20	14	25	5.29 25	.21	0.05	3.95	.26 3.95	6.7
30	14	10	5.29 10	.53	0.07	9.40	.60 9.40	6.3

Column 1 —Size of cast iron pipe class "B" and necessary cast iron fittings for a typical public highway.

Column 2 —Average sized water pipe construction corps.

Column 3 —Average number of feet of water mains installed by a corps of of size noted in column 2.

Column 4a—Fraction equals total depreciation of tools divided by number of feet of water mains installed per day. (See table 4 for depreciation on each tool.)

Column 4b—Quotient of column 4a equals depreciation cost of tools per foot of water mains installed.

Column 5 —Loss and breakage of petty tools such as chisels, small caulking tools, etc.

Column 6 —Labor cost per foot of water mains installed. "Installation" includes excavation, laying and back-filling.

Column 7a—Fraction equals depreciation cost plus breakage and loss of petty tools

Labor cost per foot

or (Columns 4b+5)

Column 6

Column 7b—Percentage of total labor cost that covers the depreciation, loss and breakage of tools.

TABLE 6

Method of ascertaining overhead charge against each construction order by the construction sub division of engineering and construction division

WATER DEPARTMENT DIVISIONS AND SUB DIVISIONS	SALARIES OF EMPLOYEES	PERCENT-AGE OF SALARIES CHARGED AGAINST CONST. ORDER	SALARIES CHARGED AS OVERHEAD
		<i>per cent</i>	
Executive Division Water Department....	\$16,100.00	11.11	\$1,788.88
Auditing Division, Water Department....	16,800.00	11.11	1,866.66
Executive Sub division, Engineering and Construction Division.....	10,400.00	33.33	3,466.66
Clerical Sub division, Engineering and Construction Division.....	21,870.00	33.33	7,290.00
Construction Sub division, Engineering and Construction Division			
1 Assistant civil engineer, construction	2,500.00	100.00	2,500.00
2 Junior civil engineers.....	3,300.00	100.00	3,300.00
3 Engineering aids.....	3,550.00	100.00	3,550.00
1 Junior clerk (cost accountant work)	1,200.00	100.00	1,200.00
1 Timekeeper.....	1,400.00	100.00	1,400.00
Engineering and Construction drafting at Bureau of Drafting.....	8,137.80	100.00	8,137.80
Total salaries charged as overhead.....			\$34,500.00
Water Department Miscellaneous Appropriations (buildings, equipment, autos, instruments, stationery, etc.....)	\$94,500.00	11.11	\$10,500.00
Grand total of salaries and miscellaneous appropriations charged as overhead.....			\$45,000.00

Total expenditures of Construction Subdivision, of Engineering and Construction Division is estimated at \$450,000.00 for year 1921.

Percentage of overhead = $\$45,000.00 = 10$ per cent.

\$450,000.00

LOCATION OF SUBSURFACE STRUCTURES IN PUBLIC HIGHWAYS

Figure 10 shows sections of public highways of various widths suggesting locations of subsurfaces so as to permit the use of trenching machines in almost all the public highways.

TABLE 7

Costs per foot of installation of water supply services in (66.0 feet public highway)

SIZE	HAND LABOR				
	Labor cost per foot (1)	Material cost per foot (2)	Depreciation cost per foot (3)	Overhead cost per foot (4)	Total cost per foot (5)
¾-inch wrought iron lead lined pipe. . .	\$0.27	\$0.66	\$0.03	\$0.10	\$1.06
1-inch wrought iron lead lined pipe. . .	.30	.78	.03	.11	1.22
2-inch wrought iron lead lined pipe. . .	.40	2.19	.04	.26	2.89
3-inch class B cast iron pipe. . . . .	.45	2.15	.05	.27	2.92
4-inch class B cast iron pipe. . . . .	.50	2.57	.05	.31	3.43

Cost of installation of valves in (66.0 feet public highway)

SIZE	HAND LABOR					
	Labor cost	Material cost	Deprecia- tion cost	Overhead cost	Cost of erection of vault	Total cost
	(1)	(2)	(3)	(4)		(5)
<i>inches</i>						
6	\$5.30	\$31.20	\$0.53	\$3.70		\$40.73
10	6.20	74.95	.62	8.18		89.95
12	6.70	92.80	.67	10.02		110.19
16	8.20	131.86	.82	14.09	\$126.59	281.56
20	15.20	281.95	1.52	29.87	169.18	497.72
30	32.10	462.14	3.21	49.75	233.08	780.28
36	41.10	1430.10	4.11	147.53	317.68	1940.52

Cost of installation of fire hydrants in (66.0 feet public highway)

SIZE	HAND LABOR				
	Labor cost (1)	Material cost (2)	Depreciation cost (3)	Overhead cost (4)	Total cost (5)
<i>inches</i>					
6	\$47.65	\$106.75	\$4.77	\$15.92	\$175.09

Standard vaults for valves

SIZE OF VALVES	SIZE OF VAULTS			THICKNESS OF BRICK WALLS	THICKNESS OF RE-ENFORCED CONCRETE SLAB	DIAMETER OF MANHOLE FRAME
	Inside length	Inside width	Average depth			
<i>inches</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>inches</i>	<i>inches</i>	<i>inches</i>
16	4.5	4.5	5.5	9	6	24
20	8.0	4.5	6.0	9	6	24
30	11.0	5.5	6.5	13	7	30
36	13.0	6.0	7.0	13	7	30

Column 1—Excavation, laying, backfilling; overhead of foremen and watchmen. Column 2—Cost of cast iron pipe, fittings, lead, rope, timber, etc. Column 3—10 per cent of the labor cost (tools and equipment, see table 5). Column 4—10 per cent of the summary of columns 1, 2 and 3. Column 5—total cost of installation.

These sections also show the possibility of placing public utilities structures in a definite location so as to safeguard against interruption of service. Should municipalities adopt a standard of location for subsurface structures in public highways, especially in the newer sections of cities, it will have a tendency to decrease the construction and maintenance costs.

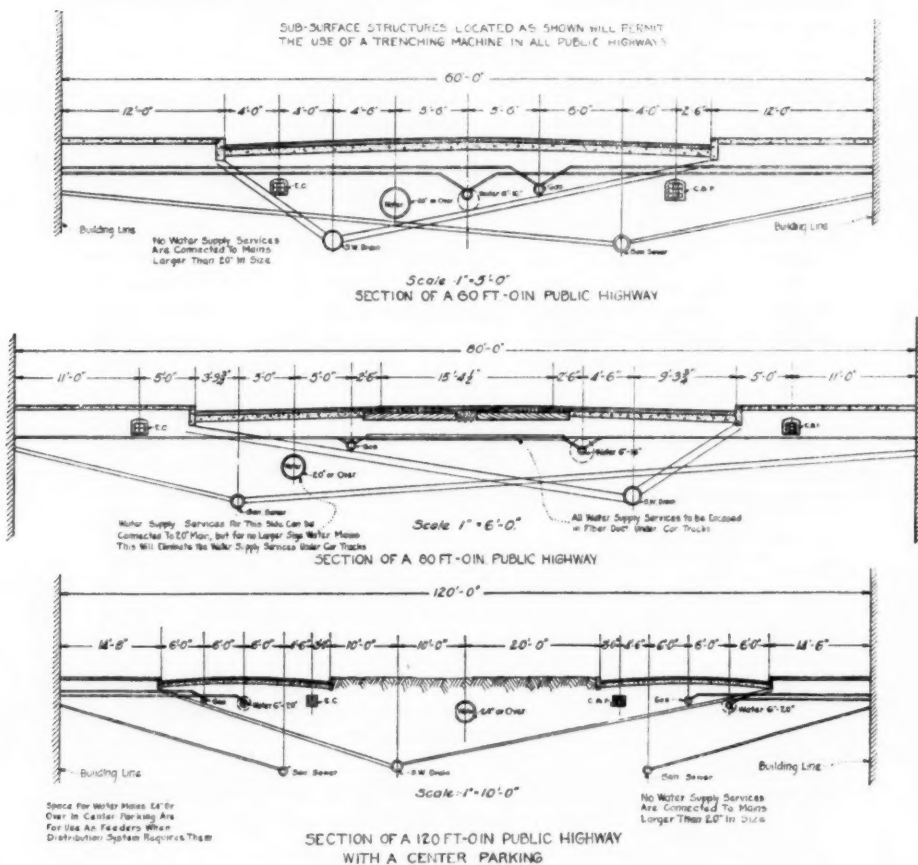


Fig. 10

The large amount of work completed by the Water Department has been due to the fact that Mr. Wm. A. Megraw, Water Engineer, has encouraged the purchase of machinery for use in the construction of water mains which procedure was inaugurated by Mr. Walter E. Lee, the former incumbent.

Due acknowledgment is given herewith to the work of Mr. C. A. Warren, Assistant Civil Engineer In Charge of the Construction Subdivision of the Engineering and Construction Division, and to his assistant, Mr. Maurice Goldstein, Junior Civil Engineer, for the cost data furnished.

THE CUTTING OF A 60-INCH CAST IRON (CLASS "B") WATER MAIN AT
NORTH AVENUE AND OAK STREET WITH OXY-ACETYLENE TORCH

The proposed changes in the distribution system at North Avenue and Oak Street required the removal of a 60 inch by 30 inch three-way and inserting of a 60 inch by 48 inch three-way and connections. As the operations of the Water Department were retarding the paving of the street, a method quicker than cutting the 60-inch cast iron pipe by hand labor was desired. An oxy-acetylene torch and operator were obtained through the local sales engineer of the Davis-Bournonville Company, and the cutting of the cast iron pipe was started immediately. The progress of the cut varied from 0.63 inch a minute to 1.3 inches a minute, the average being 0.7 inch a minute. The thickness of the cast iron pipe was 1.7 inches. Upon investigating the cut edges, small cracks were discovered around the entire circumference at intervals of 1.5 feet extending from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches from the face of the cut. This necessitated the removal of the pipe and the insertion of a new piece of 60 inch main. The new main was cut on the surface by hand labor, thus affording a direct comparison of the cutting of cast iron pipe by hand labor and with the oxy-acetylene torch. The following results were obtained. The cost of cutting the 60 inch pipe (2 cuts) by hand labor was \$232.52 including labor, overhead, depreciation and the cost of sharpening the tools. The cost of cutting the cast iron pipe (2 cuts) with the oxy-acetylene torch was \$104.23 including labor, fuel consumed, depreciation and overhead, thus resulting in a saving of 55.2 per cent. The time saved was 62.1 per cent.

As the result of research work now being conducted by the engineers of the Davis-Bournonville Company I am convinced that a practical way will be found for cutting cast iron pipe economically and quickly with the oxy-acetelene torch.

THE ERIE WATER WORKS PLANT¹

BY J. N. CHESTER² AND J. S. DUNWOODY³

The first water works plant which supplied the city of Erie was completed in the fall of 1841 and took its supply from what is known as Reeds Springs, which was piped into the city, or town as it was at that time, through pipe made by boring logs, no regard being paid to the contour of the exterior. These works were in operation until the completion of what might be termed the nucleus of the present plant, which first supplied water in 1872.

This nucleus plant took its supply from a crib a few hundred feet out, in what is now known as the bay or harbor, and is formed by a narrow neck of land known as the peninsula.

The original engines (two in number) were the beam type, Cornish Bull Pumps and notwithstanding that they delivered into a reservoir, a standpipe was constructed adjacent to the pump station to soften this action. The first installment of pipe cost \$78.25 per ton. The present reservoir, which was built in 1874, having a capacity of 33,000,000 gallons cost but \$125,000. In connection with this history it is interesting to note that one of the first board of commissioners was John Gensheimer, father of the present secretary of water works commissioners in the city of Erie.

This water works plant was naturally extended from time to time in its carrying and distributing mains and by the addition of boilers and pumps. The first supplement to the beam type pumps was an 8,000,000-gallon Gaskill, and later a 12,000,000-gallon Worthington high duty, which was again supplemented by an 8,000,000-gallon Worthington high duty, all horizontals.

To those familiar with the geography of Erie it will be known that the bay, from which the supply was taken, is connected only with the outer lake by a narrow dredged channel created and kept open by the United States government for navigation purposes, and that into

¹ Presented at the Cleveland Convention, June 8, 1921.

² The J. N. Chester Engineers, Pittsburgh, Pa.

³ Superintendent, Water Department, Erie, Pa.

this bay was then poured the entire, and even to this day the major portion of all of the sewage of the city of Erie.

The first steps toward the betterment of this supply was taken in July, 1904, when a contract was let for a 60-inch steel intake, which extended across the bay, the peninsula, and 5000 feet beyond into Lake Erie, terminating in a submerged crib, the total length being 17,000 feet. This improvement was completed in 1895 and its being put in service, naturally, greatly improved the quality of water supplied to the inhabitants of Erie.

The above mentioned reservoir was at an elevation sufficient to supply for many years the entire city, but as the city is built on a gradual slope back from Lake Erie, added years brought a growth up to and beyond the reservoir. To supply these higher elevations the mains were extended, and to all of the territory which was unable to receive an adequate pressure from the reservoir the water was pumped directly into the mains. The last-purchased Worthington or Gaskill alternated on this service, being operated constantly at nearly their capacity. Provisions for the excess were made through the medium of relief valves discharging into the low service or reservoir system.

The above describes the condition of the water works plant at the beginning of the year 1911, when a severe epidemic of typhoid visited that city. The total cases, aggregating 1060, resulted in 135 deaths.

It was by virtue of this epidemic that the firm, of which one of the authors of this paper is senior member, was employed to make a study and recommend means for the purification and betterment of Erie's water supply.

The usual study of population, prospective growth, and consumption was made, when naturally the amount necessary for the future became dependent upon whether or not the then existing flat rate would be continued indefinitely, or whether meters would be installed. The former was decided upon, at least as long as the then existing intake would provide sufficient capacity for the supply.

One of the first studies made was to ascertain the capacity of this intake. In the condition in which it then was, it was found to be approximately 20,000,000 gallons, its capacity being limited by a high place near the bay shore, not far from the pumping station. Experiments also pointed to the fact that with pumps located at approximately lake level and a siphon end provided for this intake

and means for removing the air at the high point, all of which would cost but a few thousand dollars, its capacity could be increased from 20,000,000 to 40,000,000 gallons daily. This 40,000,000 gallons was to be the maximum capacity to which flat rates would be employed. It was the intention then, as the peak loads approached this amount, to apply meters to the extent of keeping the demand well within the intake capacity, or 40,000,000 gallons.

The further result of the engineers' study was that there should be added to the plant, at once, the following units:

- A 24,000,000 gallon filter plant.

- A 20,000,000 gallon high service vertical crank and fly-wheel pumping engine.

- Two 20,000,000 gallon engine driven centrifugal low service pumping engines.

- A new boiler plant capable of delivering steam at a much higher pressure than the then existing plant, and also providing superheat for the steam.

- Coal and ash handling equipment.

- A new pump station building.

- A standpipe for high service.

This additional equipment was estimated to cost approximately \$600,000.

The view shown in figure 1, taken across the swimming pool, gives a good idea of the exterior architecture of the new pumping station, the old boiler house, and the stack.

The 20,000,000 gallon high service engine was built by the Bethlehem Steel Company, which showed a test duty of 205,000,000 foot pounds for each 1000 pounds of commercially dry steam consumed, ranks high in efficiency among the existing pumping engines of the country.

The contract for the low service pumping engines was placed with the R. D. Wood and Company, the pumps being built by the Camden Iron Works and the engines, which were vertical Marine type, cross compound condensing, by the Shephard Engineering Company of Williamsport, Pa.

With respect to the filter plant, we shall burden you only with the features that, to the best of our knowledge, are different. The first of these is the architecture brought out by figure 2, being in a measure a birds-eye view taken from the hill above the pumping station at the boiler house end, and incorporates also the State Fisheries Building in the rear of the covered settling basins. A



Fig. 1

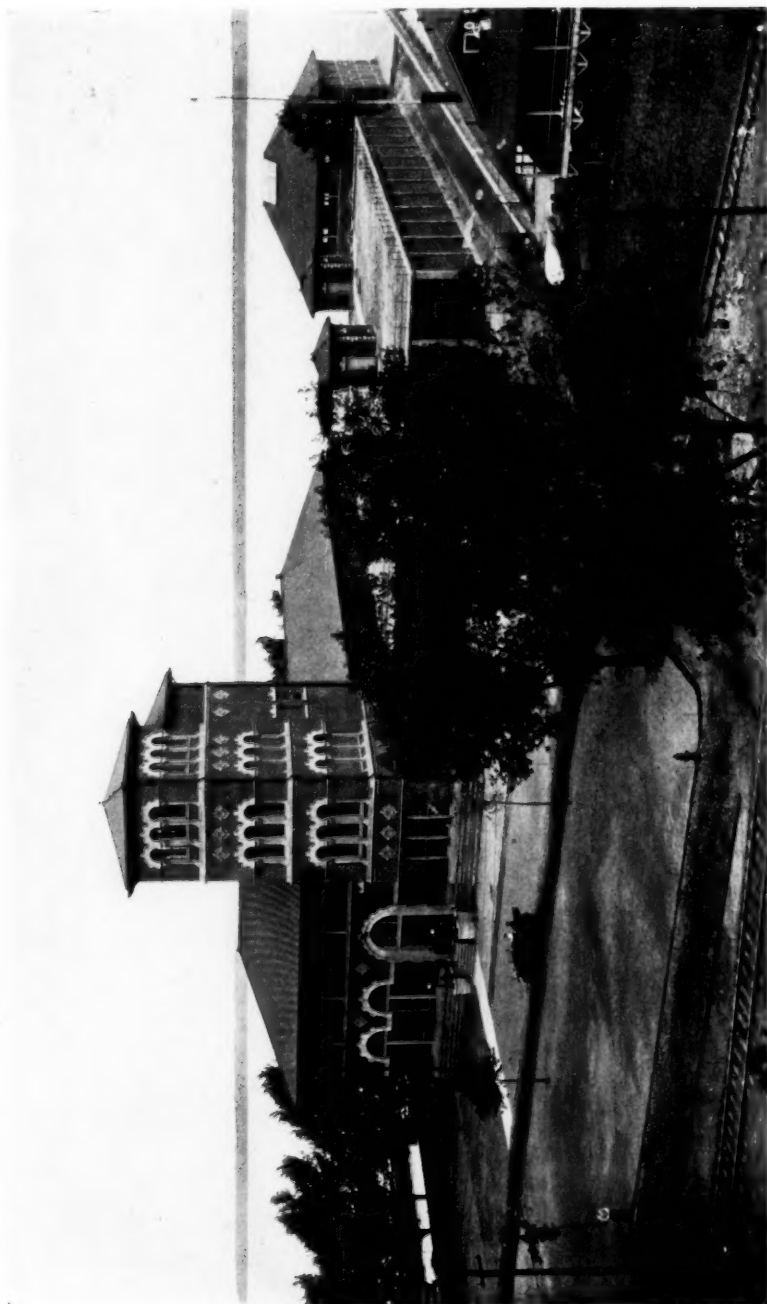


FIG. 2

feature of this that we believe to be different from most filter plants of this size and larger is the architecture, the quality of which we leave the reader to judge for himself.

This filter plant in its original design was predicated on two days natural sedimentation to be obtained from a sedimentation basin, on the peninsula which naturally permits water to be delivered to the coagulant basins at a very low turbidity.

A second feature in which these filters differ from others is in the collecting system, wherein the false bottom type of collecting and wash distribution is employed, these false bottoms being constructed of steel. It is fair to say, however, that in later designs built at other places, reinforced concrete has been substituted for this all steel design. The advantage or disadvantage of this false bottom system is what here interests us most.

These filters have been in operation since 1911, during which time neither sand nor gravel has been removed from either of the twelve 2,000,000-gallon unit tubs. Surface indications, as well as other investigations made by digging through, indicate that no clogging whatsoever has yet taken place, the wash pressure is as low as the day the filters were started, the wash water distribution apparently perfect, and the efficiency of individual beds in the combined plant beyond question.

It would, however, be unfair to attribute the above results entirely to the design. The designer can here speak for the quality of the operation, due wholly to the vigilance of his collaborator in the preparation of this paper, in that its operation has been masterful and at all times as nearly perfect as the most exacting could hope for.

Figure 3 shows the main entrance to the filter building and, most prominently, what is known as the master control table, whereon are the dials of the venturi meter, indicating the rate of flow to the settling basins; gages showing the height of water in the settling basin and the clearwell; back of these, though difficult of outline, the indicators showing the turbidity of the raw and filtered water, and beyond, and out of sight, due to the venturi meter frame, the master control lever by means of which the operator may at any time, by a slight movement, vary uniformly the output of all of the filters evenly and consequently control the rate at which filtered water is being delivered to the clear water basin.

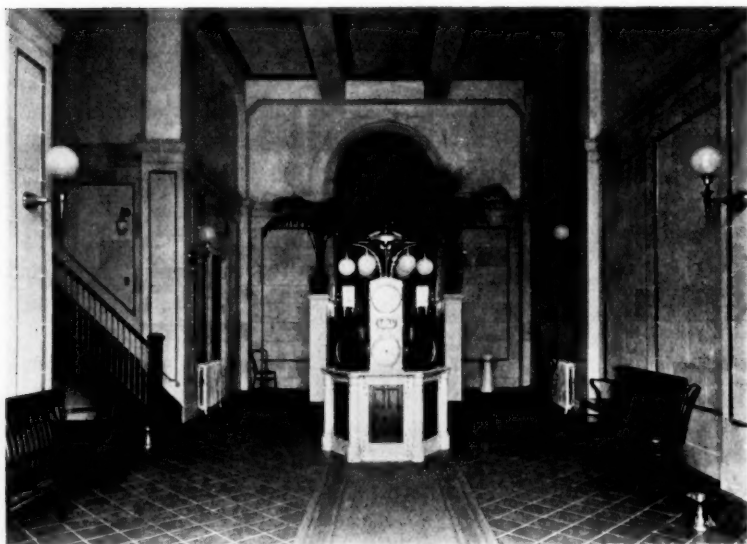


FIG. 3



FIG. 4

Figure 4 is the interior of the commissioners' room, in which these men meet Wednesday morning of each week, and it may be of interest here that these commissioners have, since the inception of this plant, been chosen from Erie's best business men. The water department is separate from the city government and under the entire control of the commissioners, who are appointed by the judges of the court. Without commenting on what the administration of affairs might be otherwise, we can testify that the conduct of the affairs of this department, since we have been connected with it in 1911, has been superb.

A room similar to the one shown has also been provided for the office of the water works superintendent.

The plant, built as it was in 1912 and 1913, during a period of depression and low prices, cost approximately only \$11,500 per million gallons. This includes the filter plant, clear water basin, coagulant basins, and intervening piping.

The plant incorporates its own electric light plant, from which is obtained the energy for lighting the station, operating the coal and ash handling machinery, automatic sump pumps for both the pump station and the filter plant, hoisting the coagulants and other minor necessities.

Duty and efficiency tests were made on all the elements, a summary of which may prove of interest. The results follow:

Low service. Since the minimum consumption at the time of the rebuilding of this station was practically 12,500,000 gallons and the maximum contemplated for the facilities furnished was 40,000,000 gallons, the head was computed for a capacity of 12,500,000, 15,000,000, 20,000,000 and 40,000,000 gallons, and duty tests for the machinery specified for each capacity.

A summary of the tests of one pump and one test of the second pump as shown in table 1.

The question may here arise as to why turbine driven pumps were not employed for this service instead of the engine driven as purchased. The answer is that at the time the first two were purchased the specifications were open for bids on this type of equipment and none were received. At the time the third unit was purchased some years later the following bids were received:

Engine driven equipment.....	\$14,700
(1) Turbine driven equipment.....	12,800
(2) Turbine driven equipment.....	15,185

TABLE 1

Summary of efficiency tests of low service pumps at Erie, Pa.

	PUMP 1				PUMP 2
	Test 1	Test 2	Test 3	Test 4	Test 3
Head specified.....	28 ft.	23 ft.	25 ft.	37 ft.	25 ft.
Head actual.....	26.87	23.34	29.22	38.29	30.48
Contract capacity, 24 hours.....	12,500,000	15,000,000	20,000,000	20,000,000	20,000,000
Actual capacity, 24 hours, gals.....	12,597,996	12,268,092	20,577,948	20,844,960	10,535,456
Duty guarantee, foot pounds.....	60,000,000	60,000,000	65,000,000	70,000,000	65,000,000
Duty obtained, foot pounds.....	63,636,000	63,426,000	69,486,000	75,554,000	68,294,300
Per cent exceeded.....	6.1	5.7	6.9	7.9	
Duty 1000 pounds, steam foot pounds.....	76,661,900	76,442,000	82,849,500	89,301,600	82,873,400
Unit efficiency.....	66.8	68.2	73.8	74.4	77.8

The guarantees were as follows:

	15,000,000 RATE AGAINST 24 FOOT HEAD	20,000,000 RATE AGAINST 30 FOOT HEAD	20,000,000 RATE AGAINST 40 FOOT HEAD
	<i>foot pounds</i>	<i>foot pounds</i>	<i>foot pounds</i>
Engine driven.....	62,000,000	68,000,000	74,000,000
Turbine driven.....	(1) 55,000,000	74,500,000	82,000,000
	(2) 60,000,000	68,000,000	65,000,000

On account of the space occupied and to preserve uniformity the conclusion was reached that the purchase of the engine driven equipment would best serve the interests of the water works department.

High service pumps. The results of the test of the Bethlehem pump on standpipe service are as follows:

Duty per 1000 pounds of steam.....	204.9 mil. ft. lbs.
Per million heat units.....	168.5 mil. ft. lbs.
Guaranteed duty per million heat units.....	168.0 mil. ft. lbs.
Mechanical efficiency.....	96.3 per cent
Slippage.....	1.255 per cent

The results on reservoir service were:

Duty per 1000 pounds of steam.....	202.5 mil. ft. lbs.
Per million heat units.....	166.3 mil. ft. lbs.
Guaranteed duty per million heat units.....	156.0 mil. ft. lbs.

On this last test, mechanical efficiency and slippage were not determined.

During both tests the steam pressure was kept above 195 pounds with the superheat at approximately 100°C. The pump head on the standpipe test was 347.8 feet and on the reservoir test 298.8 feet.

The boilers were built by the Heine Boiler Company who guaranteed an over-all efficiency of stokers, boiler setting, and superheaters of 71 per cent and on the test produced an efficiency of 71.59 per cent. The original purchase of boilers consisted of four 300-h. p. units set in two batteries of 600-h. p. each. In the guarantee the contractor agreed to accept the draft that would be furnished by the existing stack and breeching would be designed and furnished by him. The stack was 8 feet in internal diameter at the top and 175 feet high. The coal used was to be any product that the contractor might demand from the mines within a radius of 100 miles of Erie. For the test Ridgway coal was selected.

Due to the heavy demands made on the plant during the war the commissioners, for safety, installed an additional 600-h. p. battery of boilers, which were supplied by the Erie City Iron Works. At this time the stoker plant was materially changed, the coal and ash handling facilities were extended, changed and remodeled.

Since the original installation, which incorporated all of the old pumps except the Cornish engines, the 12,000,000-gallon Worthington has been removed and the space occupied by it was taken by the two low service engine driven centrifugals, and a third unit added.

There has also been installed in this low service room a high service DeLaval turbo centrifugal 20,000,000-gallon unit, the function of which is to act as an alternate or standby unit for the Bethlehem engine, the demand over 20,000,000-gallons being ordinarily supplied by the 8,000,000-gallon horizontal high duty Worthington. It is of course possible, however, to operate both the Bethlehem and the DeLaval together, but this combination is infrequent.

The duty guaranteed for the DeLaval on the heat unit basis is 117,000,000 foot pounds, as compared with 168,000,000 foot pounds of the Bethlehem.

While duty guarantees must figure largely in guiding us at the time of purchase, the actual results achieved are the facts in which we

are interested. In order that they may be here set out, the authors of this paper have caused this plant to be operated four consecutive days with only the Bethlehem in operation and have followed this with four consecutive days with the DeLaval in operation. All data necessary to the computation of the duty were taken, with all elements of the plant, other than the main units, the same and all conditions relative, with exception of the boilers, since only two were required with the Bethlehem and three with the DeLaval. The tests resulted in a *station duty* as follows:

	BETHLEHEM	DELAVAL
Per 1000 pounds of steam.....	104,000,000	72,500,000
Per 100 pounds of coal.....	66,800,000	53,200,000

Assuming that the pumpage would average 18,000,000 gallons per day for the engine year, or that each engine would deliver 90 per cent of its rated capacity throughout its life, and fixing interest and depreciation at 7 per cent, the following excesses, varying with the price of coal, could be invested in a reciprocating triple expansion over a turbo driven centrifugal.

\$2 00	\$3 00	\$4 00	\$5 00
107,400	161,100	214,800	268,500

or assuming the life of the reciprocating engine at thirty years and the turbo driven centrifugal at twenty and money to be worth 5 per cent and that the turbo centrifugal could be bought for \$40,000, which is the approximate pre-war price, then the following investments for the different prices of coal could be warranted in order to install a reciprocating engine.

\$2 00	\$3 00	\$4 00	\$5 00
164,910	222,700	280,485	338,270

The Bethlehem engine was purchased in 1912 for \$102,000. An estimate obtained on a turbo centrifugal after the war in Europe had broken out was slightly under \$40,000. The machine in service was purchased in 1916 for \$51,500.

With respect to the discharge piping around the station due to the numerous cut-ins, alterations, etc., the result of forty years operation, the commissioners in 1916 decided to replace the maze of complications and to simplify conditions. A design was prepared, therefore, for two discharge mains, one 48 inches and the other 36 inches diameter, either of which could be used for high or low service and so arranged that all pumps delivered into either. These new improvements extended to the top of the hill, or a distance of some 400 feet from the remote end of the pumping station.

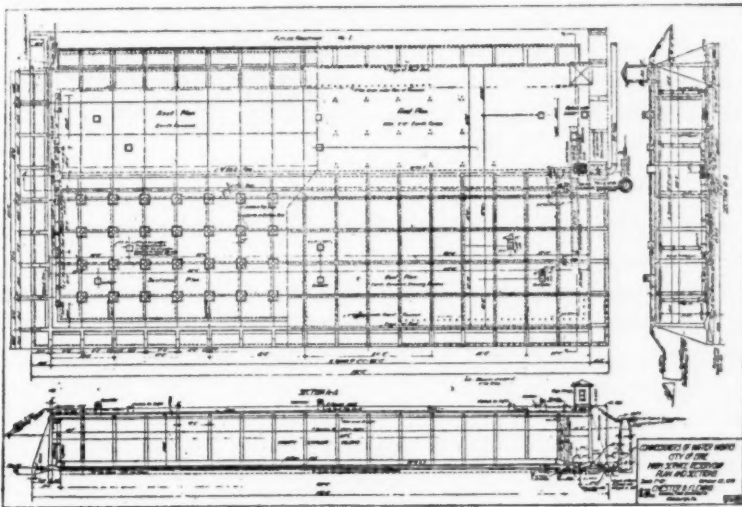


FIG. 5

The original plan for the rebuilding of this plant, while incorporating a standpipe for the high service, was to serve for a time or until funds would be forthcoming for a reservoir. A standpipe was so designed that all of the water could be pumped through the same. When the head reached a certain height the standpipe overflowed into the reservoir, but all pipe was so arranged and gated that the high and reservoir service would be entirely independent, as conditions with respect to cost might show most expedient. In the engineers' report it was declared impossible to decide which plan would be the cheaper. This statement was later confirmed in actual operation when the figures were so close that one method might prove cheaper one week and the other the next.

In 1920 the commissioners let a contract for a 5,000,000-gallon reinforced concrete covered high service reservoir, which will be completed and put in service in the fall of 1921. The only feature in which this reservoir differs from numerous others of this country is that, although numerous test holes were dug over the site and an excellent clay bottom revealed, when the excavation for the structure was brought down to sub-grade, it was discovered that the sub-grade approached, in some cases, within a few feet of the soft mud stratum. The thickness of the overlying clay between the sub-grade and this mud stratum varied over the entire area from approximately 3 feet to 10 or 12 feet, but at no place did it afford a supporting power necessary for such a structure. As a result piles had to be driven over the entire area, thus increasing materially the actual cost over the estimated. A general plan and cross section of this reservoir are shown in figure 5.

HYDROGEN-ION CONCENTRATION AND WATER SUPPLY PROBLEMS

BY FRANK HANNAN¹

In view of the increasing interest in the subject of hydrogen-ion concentration, and the growing realization of its importance in water filtration, a brief discussion of some of its aspects may not be out of place at this time.

The first essential is, of course, to grasp the nature of the ambiguity of "alkalinity" (or "acidity") as applied to water, analogous to that of "heat." The heat in the ocean is a quantity of vast magnitude; that in, say, a boiling tea-kettle, is by comparison, absolutely infinitesimal; and yet, the kettle is hotter. Similarly almost all natural waters have a more or less considerable "alkalinity;" but a large percentage of them, if tested with phenolphthalein, for example, will not react alkaline. Hydrogen-ion concentration has the same kind of bearing on problems of "alkalinity" that temperature has on heat problems; or, to take another example, potential difference on electrical problems. This distinction between hydrogen-ion concentration and titratable alkalinity—involving the fact that neither is expressible in terms of the other alone—is fundamental.

In most waters, titratable alkalinity is just bicarbonate content, but if any other hydrolysable anion is present, it will be included. The hydrogen-ions of natural water are for the most part furnished by carbonic acid. Hydroxyl-ions are present from the hydrolysis and the actual hydrogen-ion concentration is the resultant of these two factors. If, for simplicity, we neglect for the moment the neutral salts of strong acids almost always present in natural water, and their influence on the hydrolysis, we can put the matter succinctly in this way; titratable alkalinity is the total concentration of hydrolysable anions while the hydrogen-ion concentration is the degree of hydrolysis permitted by the concentration of weak acid momentarily prevailing. The paradoxical fact that the control of the hydrogen-ion concentration is, in general, exercised by the

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weak acid—and that in the so-called “weakness” of the acid resides this power—is rather important and is sometimes overlooked.

The papers of Dr. Massink and Dr. Heymann (1) on the hydrogen-ion concentration of the waters of Holland are a fine introductory study. The conception of “aggressive CO_2 ” is given great prominence. By this is meant the excess of free CO_2 present over and above the concentration necessary, in equilibrium with the bicarbonate anions, to keep the calcium present from separating out as calcium carbonate. This aggressiveness or non-aggressiveness therefore is only directly applicable to calcium carbonate. Indirectly, however, it has this most important bearing on the behaviour of a water in contact with metallic surfaces, that when the CO_2 concentration lies below the aggressive point, the water will tend to deposit a protective coating of calcium carbonate; while, when it is over the aggressive point, the protecting layer will be dissolved and the metal left open to attack. The highly corrosive character of some of the waters of Holland, as, for instance, Amsterdam (Westerveld), Enschede, Maastricht, Venlo, Wageningen, is probably the practical reason for the particular stress laid on aggressiveness.

Hydrogen-ion concentration is, of course, only one of a number of factors which decide the course of the attack on metals. To get the proper perspective for the varying weights of the several factors, according to whether the vulnerable point taken is (a) service pipes of lead, or (b) boilers, or (c) service pipes etc. of iron, many authorities must be consulted. For lead, recent papers of importance are Liverseege and Knapp (2), Weston (3), and Thresh (4). For boilers, Kestner (5) and Brühns (6). The experiments of Bosshard and Pfenniger (7) are fairly conclusive that in the absence of oxygen, carbonic acid, and electrolyte, corrosion is greatly restricted; that hydroxyl ion, as is well understood, has powerful protecting influence; and that of the commonly occurring ions, Mg^{++} and Cl^- seem the least desirable. Important as the action of water on lead and on boilers is, it is yet far outweighed for most water works by the action exerted on iron at ordinary temperatures. This has been so fully treated recently by Richardson (8) that the last word would seem to have been said. Nevertheless, Dr. Friend (9) has turned a flood of new light on the mechanism of corrosion. Such baffling facts as that sea-water shows greater corrosiveness than fresh water at 10°C ., and lesser than fresh at 30°C .; that there is a rapid increase in the corrosiveness of moving water containing dissolved

oxygen with the velocity up to a certain maximum, and that it subsequently declines until, at about 5 miles per hour, the corrosion becomes almost negligible, are satisfactorily accounted for. An illustration of the influence of varying velocity may sometimes be observed on examining a bend of considerable diameter through which the flow has been fairly constant. The outside curvature where velocity is high exhibits little or no corrosion, while the inside may show a considerable amount. The simple addition to theory made by Dr. Friend may be summed up in two points. (1) Regard must be had to those properties of iron hydroxides which have come to be known as "colloidal" and (2) the importance of catalytic activity. From the viewpoint of this discussion, the fact deserving attention is that hydrogen-ion concentration exerts considerable influence on the mechanism of colloidal and catalytic systems. It is highly probable that Dr. Friend's theory will furnish a satisfactory explanation, not only of the peculiar and intensive corrosiveness of aluminum sulphate solutions, but also of the known promotive influence of alumina on iron oxide growths. Ackermann's (10) description of the forms assumed by rust growths acquires added interest in the light of Dr. Friend's theory. The strong attractive forces on the surface of the alumina particles form the basis of mechanical filtration. The very thin, firmly adherent, coating of alumina, which results from contact with water carrying alumina hydrosols, may not be an altogether negligible factor where corrosion is concerned. If this be the case—as seems not unlikely—mechanical filtration plants have an added reason to guard against that condition of aggressive CO_2 , which will deprive them of the protection afforded by calcium carbonate deposit.

The practical value of the Tillmans curve and table—to be found in Dr. Massink's paper—is therefore considerable. Inasmuch as the data of Tillmans are those of calcium, the metal of greatest consequence for water chemistry, when notable concentrations of certain other cations, chiefly magnesium and iron, are present, the true aggressive point does not lie exactly on the Tillmans curve, as Noll (11), Rodt (12), and Kolthoff (13) point out. Some corrections are necessary for such waters.

The operation of the law of mass-action causes a relation to hold between the respective ion-concentrations of hydrogen and bicarbonate on the one hand, and, on the other, the concentration of either free carbonic acid (the usual condition) or carbonate ion.

When values have been assigned, to any two of the three, the third is also fixed. Dr. Heymann clearly explains this, and shows how the calculation is in general a simple matter. Much the same lines are followed by Greenfield and Baker (15). Unless some simplifying assumptions are made, however, the calculations become complicated. Washburn (16) develops 28 equations for the system CO_2 water, and one univalent base.

While the papers hitherto mentioned give a fairly complete picture of the equilibrium conditions in the system *calcite-carbonic acid-water*, the system *water-carbonic acid-atmospheric air* has received less consideration. It is of equal importance with the former system in arriving at the final equilibrium in any given case, and for purposes of hydrogen-ion control, it is possibly of greater importance.

The classical papers of Dr. Johnston (17, 18) and Johnston and Williamson (19) cover both systems fully and clearly with a wealth of important references. These papers put one in possession of all the important factors.

The work of Wells on carbonic acid will be found illuminating, as, for instance on Gulf water (20) and on Searles Lake (21).

Those desirous of making the hydrogen-ion determination cannot do better than read Dr. Mansfield Clark's (22) invaluable book. The sensitiveness of the hydrogen-ion concentration of natural water to its surroundings—as, for example, in the constant interchange of CO_2 with the atmosphere, in the alkali taken up from glass containers, its reaction to temperature changes, to products of biological activity, and so on, introduces a certain amount of difficulty. The divergence of opinion between the two Dutch chemists, one of whom, Dr. Heymann, prefers the colorimetric method, while the other prefers the direct method, is noteworthy. Dr. Heymann's work is all on the Amsterdam waters, while Dr. Massink's covers the whole of Holland. It is not unlikely that opinion here may exhibit a similar divergence, according as the range of waters under study is narrow or wide. It is interesting to note that Kolthoff (23) leans strongly towards the colorimetric method for water analysis.

The intimate relationship between the chemistry of natural waters and that of soils crops up again and again in the papers of the Dutch chemists. Our waters are, in effect, dilute soil solutions. Furthermore our sands themselves are species of soil. It is well known that there is an active exchange of cations between a soil and a salt solu-

tion in contact with it, and that hydrogen-ions frequently take part in the exchange, and, in general, pass from soil to water; although sometimes the reverse may occur. It is to be expected that reactions of this nature will occur in water filtration. They are probably however, so far as hydrogen-ion concentration is concerned, often outweighed in importance by the changes wrought by the high concentrations of microorganisms. Dr. Heymann on this point is instructive.

The conception of thermal optima, thermal inhibition, and thermal death-points, for the different species of microorganisms, is well-known. The same applies to enzymes, if we substitute for death, irreversible inactivation. For a given species or a given enzyme these thermal points are fairly sharply defined. In many cases the presence of "protective" substances, or other changes in the environment, may give rise to a corresponding change in the thermal point. In just the same way there appear to be for each species and each enzyme, points or zones of hydrogen-ion concentration corresponding to optimum activity, partial inactivation, and death (or total irreversible inactivation). There is this difference between heat and hydrogen-ion, that with the latter, both the upper and lower death point is tolerably sharp, and the range between the two comparatively small: while, in the case of heat, the lower death point seems rather indefinite.

As an example of the bearing of this on water filtration, the hydrogen-ion concentration of many natural waters must fall in the warmer months to a level distinctly restrictive to *B. Coli* (Chambers (24)).

The high degree of sensitiveness exhibited by living matter towards the hydrogen-ion concentration of the environment is not so very surprising when one considers that a contact between two systems of different hydrogen-ion concentration is tantamount to a difference of electric potential, according to the well-known formula:

$$\text{E.M.F.} = 0.059 \log \frac{C}{C'}$$

where $\log \frac{C}{C'}$ is simply the difference between the pH values of the two systems; and is as great, for example, for a pair of systems pH = 5 and pH = 6—both nearly neutral—as it is for a pair pH = 0, pH = 1, i.e., normal and decinormal. Just as it has been

found convenient in the practical application of electricity to construct lamps, motors, etc., to work at a definite range of voltage, and regulate the current to suit, so, it would appear, in nature, is each cell designed to function at its own particular voltage, and supplied with automatic regulators in the form of buffer systems, etc.

In conclusion it may be pointed out that probably the most fruitful application to water filtration will be found in wise wielding of the power thereby placed in our hands to vary the electrical charges on particles of all kinds in the water, from the finest colloid dispersion to the coarsest sand, rendering them, to an extent which even yet seems little realized, more amenable to effective treatment.

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CERTAIN OBSCURE RELATIONS OF DRINKING WATER TO DISEASE¹

By H. E. ROBERTSON²

To the average individual a clear water without disagreeable odor or taste is perfectly satisfactory. This is an instinctive judgment developed by an inheritance extending back to the beginning of life. Such water through all time has satisfied his thirst and if he acquired disease by drinking it, personal and communal ignorance kept him blissfully unaware of that fact—the water still quenched thirst.

It is only comparatively recently that we have recognized the evils which may follow the contamination of drinking supplies by human sewage. Thus we have been led to the adoption of various and fairly satisfactory methods for the prevention and cure of these and related defects in our urban water systems. In short we have materially advanced beyond our remote ancestors' conceptions of what constituted proper drinking water. We recognize and endeavor to side step the menace of invisible human excrement. This achievement is no mean triumph. Aided and abetted by the bacteriologists and the epidemiologists, sanitary engineers have made practical and trustworthy our defenses against water-borne parasitic diseases.

The ordinary citizen receives, however, all this regulation of his drinking water, with only the theoretical approval of his intelligence. His real standards still remain on the old plane established by the instinctive reactions of untold generations. The rationality of these instincts and their inherent contribution to the survival of the human species must be freely granted. Our primeval forebears ate their food either raw or only partially cooked and they added nothing to their natural drinking water. They had little need to think of salts, extractives or vitamins. Nature's table was bountifully

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provided with these necessities and ancient customs did not interfere with their utilization.

With the development of what we are pleased to call civilization the preparation of food has become more complicated and the provision of a common protected source of drinking water a recognized measure of safety. Meats are cooked by heat and vegetables are boiled and the people's supplies of water are filtered, sedimented, often softened, and usually sterilized. By these means we have partially protected ourselves against parasitic diseases. To the average sanitarian, to say nothing of the average individual, these changes appear to represent a net gain, an advance in the protection of human life and health which constitutes an entirely plus factor.

Unfortunately the matter is not quite so simple. It is an almost universal experience that no forward step in material progress is ever made without a distinct defect to offset the greater gain and it is by the broad minded recognition and correction of these defects that real advances are justified and made secure. So it is that by the artificial improvements of natural eating and drinking supplies, definite and often serious losses have occurred and occasionally may have even counterbalanced the admitted gains of modern sanitary methods.

Extended discussion of these very complex problems would be hardly possible or fitting at the present time. Indeed the actual extent of our accurate knowledge in regard to the exact needs of the body and how best these needs may be served is exceedingly meagre. We know for example that certain mineral salts are absolutely necessary, if metabolism is to be maintained at a normal balance. Calcium, sodium and potassium salts, iron, phosphorus and iodine are some of these essential constituents. Lack of calcium causing pathologic bone and tooth formation, and insufficient chlorides with serious disturbances of the equilibrium of the blood plasma are fairly well established. Iron is necessary for hemoglobin building and phosphorus plays an important rôle in the formation of many of the lipid elements, particularly of the nervous system. Only recently it has been fairly clearly demonstrated that endemic goiter is the result of a deficient supply of iodine in the drinking water. This particular disease has long been a subject of speculation and investigation and many years ago there was collected considerable evidence which indicated that the incidence of ordinary simple goiter (not toxic goiter) in some way was con-

nected with the drinking water. By the work of Marine and his pupils this suspicion now becomes a certainty. Not only has goiter been produced in animals by giving them water deficient in iodine but also by supplying to the water small quantities of this element the goiters have been caused to disappear. In an experiment with the school children of Cleveland, of 2190 who were given a small amount of iodine at regular intervals, only 5 developed goiters, while among 2305 not given iodine, 495 showed enlargement of the thyroid. Moreover out of 1182 children already having goiters and receiving iodine 773 revealed reduction in the size of the goiter while in 1048 similar cases without iodine only 145 showed a decrease.

These remarkable demonstrations have a double significance. Not only do they show the cause and prevention and cure of simple goiters but they also indicate that under certain conditions supposedly satisfactory drinking water may actually carry a potential menace to the health of our people. Unfortunately not many other vital constituents of drinking water have been so fruitfully studied as iodine but there are sufficient evidences in existence to warrant the belief that other deficiencies may be present in certain geographic areas and may be producing equally serious results.

Still more vague must be the estimation of the influence exerted by an *excess* of these mineral elements. With that quality of water termed "hardness," the measurement of its degree and its deleterious action on steam boilers and the housewives' tea kettles we are all familiar. We even deprecate its disagreeable properties when used for washing and bathing purposes and some of us feel fairly certain that its action on the skin is sometimes distinctly harmful. So important has this subject become that elaborate and expensive measures are now used for "softening" such water. But what the effects of the prolonged drinking of such water may be has not yet been determined. Sometime ago I was struck by the frequency with which I found calcium deposits in the kidneys of people who had lived in certain districts of our country but further observations are needed to establish the significance of this observation. In short we have few accurate data which may serve to evaluate the effect of abnormal increase in our food or drink of any particular salt or element.

Even more vague is the subject of vitamins in relation to drinking water. Up to the present time these substances have been shown to have a vital relation to health and disease, but they have been

studied almost exclusively in the foods that we eat and not in the water that we drink. While we are fairly certain that distilled water is not an ideal beverage, whether its insufficiency is a poverty of salts or organic vitamins or both, has not been determined. Just as in the thorough cooking of foods to render them sterile, more palatable and more readily digestible, we find that certain important mineral constituents are lost and the vitamins often destroyed, so it may prove also true that in our intensive treatment of drinking waters for the purpose of making them *sanitary* certain undesirable *by-products* of this treatment may be causing pathologic conditions whose importance we are at present unable to estimate.

One hesitates to critically comment on procedures which have repeatedly proved their life and health saving worth. But, as I have already emphasized, it is only by a searching survey of all the effects of even the most successful measures that continued progress becomes possible. It is not, however, my purpose and neither is it within the range of my ability to review the possible deleterious actions of hypochlorites or chlorine when used to purify municipal water supplies. I merely desire to indicate, that, after having conclusively demonstrated the usefulness of these chemicals both in emergency and in routine practice, the experiment is now being conducted on a large scale, and that the time is now ripe to carefully scrutinize any suspicion of unfavorable action which these substances may be directly or indirectly exerting on the welfare of the human organisms which they serve. Once having solved the problem of combating the menace of certain water and food borne diseases, we cannot afford to disregard those more insidious, slow acting and less fulminating conditions which just as surely harm the effectiveness or bring about the disintegration of the body's vital capacities. The more obscure and perplexing the puzzles become, the more able and painstaking must be the efforts at their solution.

The outlook for continuous advances in this direction is particularly hopeful. Whenever the problems of the protection of the health of the public have involved their special fields, sanitary engineers have always responded by the elaboration of practical and efficient measures. Whenever their science or any related science has indicated the need they have ever willingly and successfully shouldered the burden.

Our faith in the future has had abundant justification in the past and we may confidently expect that once it can be definitely demonstrated that certain constituents of our communal drinking supplies are either harmfully deficient or harmfully in excess, the response by a definite remedy will surely be forthcoming. Our present demand, as in all fields of scientific endeavor, is for more certain light.

SERVICES¹

MR. J. WALTER ACKERMAN:² The practice I have always followed in installing services is to use the lead gooseneck. Other people use a complete lead pipe, but I was quite surprised to learn that a great number of people apparently are using an absolutely rigid connection; that is, they simply put in a corporation cock on the side of the main and screw a wrought iron pipe directly into it, and that is all there is to it. They claim that they have no trouble. If that is a fact and anybody here has had that experience, it seems to me it is worthy of a great deal of consideration, because there would undoubtedly be a great saving in the expense of putting in service pipe. Might I ask if there is anyone in the room who uses that practice here, will they please raise their hands? (Several members responded.)

THE CHAIR: In the New England district, I think it is quite common practice.

MR. ACKERMAN: Why do we not all use it, if it creates no trouble?

MR. BROWN: Because of different soil conditions.

MR. ACKERMAN: I do not see how the soil condition has anything to do with it unless you use all lead pipe. I am simply looking at it from the standpoint of construction. Where I happen to come from at the present time is the cold North, where the frost goes down deep. When I arrived there I found that the practice was to use a lead gooseneck, but it is put in absolutely straight, on the side of the main and going absolutely straight, with a short gooseneck only a foot long. It is not actually a gooseneck, because it is absolutely straight, but it is a lead connection. All the other fittings are made sufficiently large, so that when it does freeze up, as frequently happens, and one cannot thaw it by electricity, it is possible to thaw it by running a small pipe on the inside and pumping through it hot

¹ Discussion at the Cleveland Convention, June 10, 1921.

² Superintendent, Water Board, Watertown, N. Y.

water. By laying the pipe absolutely straight, you can thaw it all the way through to the main. Prior to my present location, in Watertown, New York, we used a lead gooseneck with a curve. Of course you could not rod through that. As to the other features of the article, who pays for the installation and who maintains it, I might say that I have had two practices, namely the consumer pays and maintains in the first case, and in the second, he pays but the water department maintains. It is my belief that either the latter practice or that of having the water department lay and maintain is the best.

MR. A. PRESCOTT FOLWELL:³ Mr. Ackerman had in mind, I think, not so much the chemical reason for putting in the lead pipe as the mechanical reason. I was brought up also to think that a gooseneck was essential to prevent a settlement of the soil around a pipe from possibly breaking the connection between the service and the main. Where we have a soil that carries a large number of small stones from the size of a "niggerhead" down to the size of your fist, or of large gravel, there is danger that a stone of some kind will land on top of the service and carry in addition some superimposed weight, and with the settlement of the soil underneath the service, considerable weight will come upon it and tend to break it off; while with a little play offered by a lead gooseneck, that can be largely avoided, and that is what I presume Mr. Ackerman had in mind. I wonder whether there are not a good many partial breaks in the case of straight iron pipe services without any lead pipe that are not known or suspected by superintendents?

There was another point Mr. Ackerman made that I think referred to putting the cock on the side of the pipe or the top. The same argument holds good to my mind for putting the cock on top of the pipe rather than at the side, because again you avoid the tendency of anything lodging on top of a cock and breaking it off if the earth should settle under it, or at least stripping the thread and loosening the joint in the main. There are not many threads between a corporation cock and a thin cast iron pipe, and it is not very difficult to strip them so that the water will squirt out in a stream. In my young days I built both water works and sewers, and at one town we were running a sewer trench right alongside of a water main, without any sheathing. We came to a factory where they had a

³ Editor, *Public Works*, New York, N. Y.

2-inch service but had multiple cocks distributed about 5 feet apart, along the main connected up to this service pipe. In spite of all instructions and everything except actual blows, it was almost impossible to prevent the Italians from using the corporation cocks as steps for getting out of the trench. On one occasion the corporation cock at one end of this row of half a dozen gave way under the weight of an Italian who then excitedly jumped onto the next cock to get out, and before he got out, he had broken off all six of those corporation cocks. If those cocks had been on the top instead of on the side, that would not have happened. If there is no good reason for placing the cock on the side of the pipe rather than the top, it does seem to be an argument for putting it on the top that this may prevent the rupture of the cock or the springing of a leak.

TAPPING LARGE STEEL MAINS UNDER PRESSURE¹

By D. F. O'BRIEN²

There is a great deal that may be said on the subject of tapping large steel mains under pressure, but with much of it you are already familiar. As there are so many interesting subjects which superintendents have to discuss on this date, I do not think it would be just to you to take up your time with a repetition of details with which you are already acquainted.

Both the operating mechanism for cutting the steel mains and the method of doing the work are similar to those used in making connections to cast iron mains and will therefore need no description. This discussion will be confined, therefore, to the difficulties which must be overcome in making connections to large steel mains under pressure.

It is told of Michael Angelo that, when working on the Sistine Chapel, a fellow artist approached him and remonstrated with him on the time he was devoting to an obscure corner of the ceiling, saying, it is but a trifle, a detail. The Master answered "yes, that is true, but trifles make perfection and perfection is no trifle." The making of connections to large steel mains under pressure, satisfactorily, is a matter of details, trifles, and paying absolute attention to them.

Steel mains, whether made by the alternate inside and outside courses, or put together by telescopic taper joints, are never truly cylindrical. Measurements taken only a few feet apart on the same section of pipe will frequently show marked differences in contour. This fact occasions the principal difficulty in making connections to steel mains, as the lead joint between the tapping sleeve and the pipe cannot be satisfactorily calked unless the joint is approximately uniform and of the correct thickness. To secure that condition it is necessary to get the dimension of the pipe where the sleeve encircles it at both ends, also the dimension from the vertical axis around to the horizontal seam, the width of the seam, the height of the rivet head and the contour of the pipe at these several points.

¹ Presented at the Cleveland Convention, June 9, 1921.

² President and Manager, the A. P. Smith Mfg. Co., East Orange, N. J.

The contour of the pipe may be determined by encircling it with a flat ring whose diameter is larger than the largest axis of the pipe. This ring is adjusted on the pipe by thumb screws placed on the horizontal and vertical axis. The distance from the inner edge of the ring to the pipe is noted at intervals of 30 degrees around the periphery. From those dimensions the contour may be determined with enough exactness for practical purposes. The pattern for the sleeves is made to conform to the dimensions and contour of the pipe, due allowance being made for the desired thickness of joint. A cylindrical sleeve made to the nearest dimensions to suit the pipe would result in the sleeve and main being metal to metal at some point, while at others there would be $1\frac{1}{2}$ to 2 inches of lead, which could not be satisfactorily calked. For this reason we must be certain that, with the correct pattern, care is exercised in the foundry in the molding and cooling of the casting to see that it is in accordance with the pattern. If care is not taken, deformation will result, necessitating scrapping the casting or causing trouble in doing the work.

The sleeve casting, being tested and found correct to dimensions and contour, is adjusted on the pipe in the same manner as in doing the work on cast iron mains. In pouring and calking the joint, however, greater care must be exercised, as the sheet steel presents a comparatively smooth surface and the lead will not form as close frictional contact with it as it does with the rough surface of cast iron pipe. For that reason it is advisable to pour the lead as hot as possible. The calking should be done only by one who has had experience in working on steel mains as the lead must be thoroughly upset and driven hard, but in doing so the pipe must not be deflected.

In operating the cutting mechanism in both the drilling and cutting operations, particular attention must be given to keep a light continuous feed. If the feed is interrupted the cuttings will be ground between the cutters and the pipe, thus destroying the cutting edge which makes necessary the removal of the cutter for resharpener—something that should be avoided. On the other hand, if the feed be heavy or erratic, the pipe is so flexible that it is easily deflected and the lead joint broken or worse still, one of the teeth of the cutter may be broken which means the removal of the cutter.

These several obstacles may be readily overcome by absolute attention to the several details, taking care that this work is entrusted to men who have had experience in this particular line.

SHORT-COMINGS IN THE PRESENT STANDARD METHODS OF WATER ANALYSIS FROM THE OPERATOR'S VIEWPOINT¹

BY LEWIS I. BIRDSALL²

The following paragraph is quoted from the Preface to the First Edition of the Report of the Committee on Standard Methods of Water Analysis. The italics are inserted by the present writer.

Detailed descriptions of the various methods recommended are given in concise form, covering the essential features of each determination. *It is assumed that those using these directions are thoroughly grounded in the fundamental principles of chemistry and biology, and that they are also familiar with the leading literature upon the subject.* So many satisfactory text books upon chemical analysis in general and on water analysis in particular are in existence that it is unnecessary to give a complete detailed description of all procedures, but it is fully recognized that in many cases the adherence to certain details is an essential matter, and hence for the newer methods they are incorporated in this report.

Conditions have changed materially since 1904 when the above quoted paragraph was written. At that time well established laboratories all over the United States and Canada were using different methods of water analysis and the great question for the Committee on Standard Methods to solve was that of selecting methods of analysis which would be adopted as uniform procedure by all these laboratories. The men who formulated the report and those in charge of the water laboratories at that time were all "thoroughly grounded in the fundamental principles of chemistry and

¹ At the request of the Editor the writer presents in this paper his criticisms of the present standard methods of water analysis from the viewpoint of a water purification plant operator. The paper was prepared in order to indicate what line of action the Association might take to increase the value of "standard methods" to the operator.

² Superintendent, Purification Division, Water Works Department, Minneapolis, Minn.

biology," and were no doubt "familiar with the leading literature upon the subject." During the seventeen years that have elapsed, however, there have been great changes both in the number of laboratories analysing water and in the calibre of the analysts themselves. The great increase in the number of water filtration plants and the use of chlorine for water sterilization, alone or in conjunction with filtration, have produced a new and varied group of water analysts. Many small water purification plants are now creditably operated by men who have never had an opportunity to become "thoroughly grounded in the principles of chemistry and biology" or to acquaint themselves with the "leading literature upon the subject," but who have been taught by a representative of the State Board of Health or by some other competent person to make a few chemical and bacteriological determinations as outlined in Standard Methods of Water Analysis, the only text book that they possess. We should endeavor to educate such men whenever possible to a broader knowledge of analytical methods. In the meantime, however, the effluent of the water purification plant must be kept as pure as possible and the health of the people served must be protected. After all does not the ultimate value of water analysis rest upon the conservation of health, and is not the health of the community the final criterion by which the purity of a water supply is judged?

The Report of the Committee on Standard Methods published in 1904 has been evolved into the present Standard Methods for the Examination of Water and Sewage, with few changes in the chemical methods of analysis and many changes in the bacteriological methods during the intervening years. The present Standard Methods has become the standard text book, in many cases the only text book in the hands of men who are in charge of the operation of small water purification plants. Why then should it not be admitted that Standard Methods is a text book and that some attempt should be made to meet the demands that are made upon it?

It is the purpose of the writer to point out here the changes that he believes should be made in Standard Methods and to suggest new material that should be added in order to meet the present day demands of the water purification plant operator. The discussion of the various subjects will be made under the headings as they appear in the fourth edition of Standard Methods.

COLLECTION OF SAMPLES

Bottles

The formulae for cleaning solutions should be included.

Representative samples

Directions should be given for the collection of samples of water at the surface and below the surface of lakes and rivers. A cut should be inserted of some sampling device for holding the bottle when taking samples of water below the surface.

PHYSICAL EXAMINATION

Temperature

The words "if taken" should be omitted because temperature data are frequently valuable and the determination should be made. A cut showing a thermophone should be inserted.

Turbidity

The turbidity determination is undoubtedly important but it appears to the author that undue space has been allotted to a description of the methods employed at the expense of brevity elsewhere in Standard Methods. The statement that the observation should be made "in the middle of the day, in the open air, but not in sunlight, and in a vessel so large that the sides do not shut out the light so as to influence the results" is delightfully entertaining but highly discouraging to most analysts. Would it not be much more scientific and satisfactory to every one concerned to accept the suggestion of the United States Bureau of Standards that it prepare a silica standard for distribution to water laboratories? The Bureau has recently shown that silica standards in use in various laboratories, all made according to the directions given in Standard Methods, vary greatly.

A cut showing a standard United States Geological Survey turbidity rod should be inserted.

A table should be added to show the quantities of the stock silica suspension to be used with distilled water in making up the silica standards.

A cut showing a candle turbidimeter should be inserted.

Color

A table should be added to show the amounts of stock color solution to be used in the preparation of the color standards.

The writer has found the Berkfeld Army filter number 3 very satisfactory for filtering turbid water previous to determining the true color.

A cut of some simple device for holding color tubes and having a movable lower mirror for reflecting the light through the tubes and upon a movable upper mirror would be a valuable addition.

A cut of the United States Geological Survey color tubes and discs should be inserted.

CHEMICAL EXAMINATION

A general statement should be given of the value of the various chemical determinations in the analysis of water from various sources. For example the author has found that the ammonia nitrogen, albuminoid nitrogen, nitrite, nitrate and residue on evaporation determinations have little value as routine tests in the control of a water purification plant. These determinations may be of value in arriving at a fair opinion of the quality of an unknown water.

The cut of the device for holding color tubes would also serve as a suggestion for a rack to hold the nitrogen standards if the device were made long enough.

RESIDUE ON EVAPORATION

Total residue

There is confusion caused here by the recommendation of either 103°C. or 180°C. as the temperature for heating the residue. One temperature only should be selected and made authoritative so as to make all results comparable. The same criticism applies to the determination of suspended matter by the Gooch crucible method.

HARDNESS

The general definition of hardness should be rewritten with a view to clearness of expression. Some statement should be added of the reasons why a hard water is undesirable for steam boilers and for domestic use.

An effort should be made to discourage the use of the expressions "temporary hardness" and "permanent hardness" as they have outlived their usefulness. The author prefers a division of total hardness into carbonate hardness and non-carbonate hardness as these terms more nearly meet the actual conditions found in boiler water treatment and water softening problems.

Total hardness by soap method

If it is permissible to use either ethyl alcohol or methyl alcohol in making the standard soap solution then this statement should be added.

In the table showing the amounts of hardness equivalent to the various amounts of soap solution added there is an error which has survived all editions of Standard Methods. The hardness equivalent to 3.5 cc. of soap solution should be 39 instead of 38.

The author regrets that the volumetric methods for the determination of calcium and magnesium have been omitted in the later editions of Standard Methods as these methods are found useful in boiler water analysis.

Alkalinity

The statement in the First Edition of Standard Methods relative to the reasons for using phenolphthalein as an indicator in determining carbonate alkalinity is preferred to the condensed statement appearing in the Fourth Edition.

The colorimetric method of hydrogen ion determination should be described and the use of this method should be encouraged.

Mineral analysis

A statement might well be included to indicate a uniform method of reporting the results of mineral analysis as there is at present a great lack of uniformity in such reports. The author prefers the ionic form for such data. If the ions found to be present are to be combined in the form of definite chemical compounds, a definite order of combination should be indicated.

Dissolved oxygen

There should be a cut illustrating the device for use in collecting samples of water from a lake or river.

ANALYSIS OF SEWAGE

There should be a general heading "Analysis of Sewage" and a statement to indicate the determinations that are recommended in sewage analysis.

BACTERIOLOGICAL EXAMINATION

Sample bottles

The author has found metal capped glass stoppered bottles to be most satisfactory for use in collecting samples for bacteriological examinations.

Preparation of culture media

The phenolphthalein method of titration for adjusting the reaction of culture media should be omitted, substituting therefore the hydrogen ion concentration method with full description.

Collection of samples

There should be given specific directions for the collection of samples from different sources. Sterilization of taps by flaming previous to the collection of samples should be emphasized. A cut should be inserted showing some simple device for holding the bottle when taking samples below the surface of basins, lakes or rivers.

Interpretation of results

It is highly desirable that there be included a detailed statement on the interpretation of results, both chemical and bacteriological, even though the title has to be changed from Standard Methods for the Examination of Water and Sewage to Handbook for Water Analysts or some similar title. It appears entirely logical to include such material since Standard Methods has already been accepted as a text book.

There should also be included some statement relative to standards of quality. The United States Treasury Department Standard should be given, not because it is the universally accepted standard, but because of the fact that many water purification plants

are required to meet this standard, if the water they supply is to be certified by State Boards of Health for use by interstate carriers.

In the mind of the author there is only one standard for the bacterial content of a filtered water and that is sterile water—an ideal standard, to be sure, but one that is well worth seeking.

SANITARY SURVEY

A statement should be made of the value of a sanitary survey when determining the purity of a water supply. There are many cases where such a survey has been the deciding factor and has produced results entirely at variance with the analytical data.³

CONCLUSION

The writer is fully in accord with the recommendations of the Committee on Official Standards of Water Analysis of the American Water Works Association as published in the *JOURNAL* for September, 1921.

After such an official committee has been organized, with representatives from the various cooperating societies named, it should be its duty to revise the Standard Methods yearly and to have the same published in an annual edition, paper bound if necessary to reduce the cost.

New and frequently valuable methods of analysis, especially bacteriological, are appearing in various journals and are adopted by some laboratories whereas others continue to use the older methods. The result is a lack of uniform methods of analysis and of comparative data.

If we admit that standard methods of water analysis are essential for use in all laboratories, for the purpose of securing data that are comparable, then such methods should be as comprehensive as possible, should be stated in simple terms and in sufficient detail so that the need for reference to other text books is reduced to a minimum.

³ *JOURNAL*, May, 1920, page 278.

THE REACTIONS OF CULTURE MEDIA¹

BY GEORGE C. BUNKER² AND HENRY SCHUBER³

In this paper we give the results of our experience in determining the hydrogen-ion concentration of some of the commonly used media by means of color standards; we call attention to some "delightfully indefinite" statements—to use an expression of a well known chemist in a private communication—in the section of *Standard Methods* and we propose some tentative hydrogen-ion concentrations for lactose broth, nutrient agar, and Endo's agar.

The reactions of culture media in use in the laboratories of water works and the methods of adjusting the reactions are live subjects today. While the trend of opinion of bacteriologists appears to be in favor of the adjustment of the reactions of culture media by determining the hydrogen-ion concentration, yet in many laboratories, large and small, the phenolphthalein titration method is still in use. Some men continue to use the phenolphthalein titration method because they have not had the opportunity to study and work on the determination of hydrogen-ion concentrations. Others consider it inadvisable to change the reactions of media which they have used for ten or more years. Some, on the other hand, feel that a definite hydrogen-ion concentration for each medium is an unnecessary refinement. To many the term "hydrogen-ion concentration" appears too formidable because they have not seen a clear and concise article on the essential features pertaining to its application in a water works laboratory.

We venture to say that the majority of chemist and bacteriologists in water works laboratories are not members of the Society of American Bacteriologists and consequently have not seen the articles on various phases of "hydrogen-ion concentration" in the JOURNAL

¹ Read by title before the Chemical & Bacteriological Section, at the Cleveland Convention, June 9, 1921.

² Physiologist to The Panama Canal. In charge of purification of water supplies on Canal Zone and testing laboratories of Municipal Engineering Division of The Panama Canal. Ancon, Canal Zone.

³ Chemist and Bacteriologist at Miraflores Purification Plant. Ancon, Canal Zone.

of this Society, the initial contribution having been made by Clark and Lubs (1917) and continued intermittently by them as well as others up to the present time; the latest article of great practical value being that of Medalia (1920). We can not expect the younger men, recently out of school, who are starting out on a modest salary, immediately to join the Water Works Associations, the Society of American Bacteriologists, the American Chemical Society, and to subscribe to the *Engineering News-Record*, *The American City*, *Engineering & Contracting*, and others. Neither can we see in the dim vista of the future many water commissioners, managers of private water companies, or corporations furnishing their laboratories with the journals of the above societies. There are probably more copies of the *Standard Methods of Water Analysis*, published by the American Public Health Association, in the hands of chemists and bacteriologists in water works laboratories than of any other book, yet in the fourth edition (1920) we find only one-third of a page devoted to the determination of the hydrogen-ion concentration of culture media. In the "Bacteriological Bibliography" of this edition there are sufficient references to the literature to enable a man located in a large city containing a large library to prime himself on the subject but for the man located in a medium sized water works laboratory there are no such library facilities. If he is sufficiently interested he must order the various journals at a considerable expense, because he can not always judge from the titles which one contains the article of greatest practical service. In this bibliography there is no reference to the excellent summary of the subject of hydrogen-ion concentration by the Committee (1919) on the descriptive chart of the Society of American Bacteriologists, which was published in the 1919 volume of the *JOURNAL* of this Society. In reference to a discussion of the detection of acid production of bacteria the Committee wrote as follows:

The above discussion will be readily intelligible to any reader who has an understanding of H-ion concentration and of the meaning of the symbol pH. There would, indeed, be no point in discussing this subject further, if the research worker alone were concerned, because Clark and Lubs recent paper (1917) is readily available and treats the subject as fully and adequately as could be desired. The new chart, however, is intended primarily for instruction and it is felt that teachers may desire a brief discussion of hydrogen-ion concentration for class-room or reference use. As there is at present no bacteriological textbook, so far as the committee knows that discusses the relation of acidity and reaction of media to H-ion concentration, and as copies of this

report can be obtained from the secretary⁴ of the Society at about cost price, it seems well to summarize the subject here. Nothing new, however, is added in the following pages to what previous writers have said.

While we understand that the *Standard Methods* is not intended to serve as a text book, it does appear, under the existing circumstances, as though more space should have been allotted to the subject of hydrogen-ion concentration in the fourth edition. We believe that the purchasers of copies of this edition would have welcomed the inclusion of the above mentioned summary of the Committee of the Society of American Bacteriologists even if the price of the book had been increased.

To those men who wish to determine the hydrogen-ion concentration of culture media and to adjust the reaction of the latter to definite concentrations we strongly advise the purchase of (1) Clark's book (1920) on *The Determination of Hydrogen Ions*, which contains an indexed bibliography of 1100 references; and (2) No. 5, volume 5 (September, 1920), of the *Journal of Bacteriology*, which contains an excellent article by Medalia (1920) on "Color Standards for the Colorimetric Measurement of H-ion Concentration pH 1.2 to pH 9.8." This article gives a practical method of preparing color standards for use in bacteriological laboratories and we have quoted quite extensively from it in this paper. We are not certain that single numbers of a volume of the *Journal of Bacteriology* are sold, in which case the complete volume must be purchased at a cost of \$5.00 unless reprints may be secured from the author.

There is a Committee of this Association on Official Standards of Water Analysis. Is it not advisable for the Association to arrange for the cooperation of this Committee with those of the American Public Health Association, The American Chemical Society, and the referees of the Association of Official Agricultural Chemists so it may take a hand in the preparation of the next edition of the *Standard Methods*? These methods are certainly used in a sufficient number of water works laboratories to entitle a Committee of the Association to share in their preparation. We believe that the *Standard Methods* may be made more useful to the men in water works laboratories than it is at present. Moreover we doubt the wisdom of the conciseness of the description of some of the methods and subjects. It is very well to assume that "Those using these directions are

⁴ Major A. Parker Hitchens, M. C., Army Medical School, Washington, D. C.

thoroughly grounded in the fundamental principles of chemistry and biology, and that they are also familiar with the leading literature upon the subject," as expressed in the preface to the first edition of the *Standard Methods*, but the experience of the senior author of this paper with laboratory assistants and superintendents of purification plants, during the last eleven years, some of whom could be classed as excellent, some as good, and the remainder as poor, has convinced him that the methods should be written up in more detail to be of the greatest service to the majority of the men who use them. He also believes that there should be included pointers about certain operations to be avoided and why they should be avoided; suggestions about the preparation and standardization of various solutions; pointers about the frequency of restandardization of solutions; notations on fading of color standards, such as in the determination of iron; and so on. No matter how thoroughly a man is grounded in the fundamental principles of chemistry and biology, he will miss many points which he will pick up later by experience. Why not give the men who are starting out in water works laboratories the benefit of some of the points which have been picked up from time to time during several years experience? Why not make the *Standard Methods* a little more human, a little more interesting, and a little more helpful?

The adjustment of the reactions of culture media to definite hydrogen-ion concentrations was adopted as a standard procedure in the Testing Laboratories of the Municipal Engineering Division of the Panama Canal in February, 1919, for reasons clearly expressed by Clark (1920):

In the old process of adjusting the "reaction" of culture media an aliquot of a given batch was titrated to the "first faint pink" with phenolphthalein. This was supposed to give the quantity of alkali required to bring the medium to "neutrality." Then since experience had shown that a particular medium supported growth best when made more acid with a certain percentage of acid reckoned from "neutrality," the required per cent of acid, less the difference between it and the equivalent of alkali required to reach "neutrality," was added to the main batch of medium. The result of this practice was that any change in the composition of the medium changed the final pH which a given per cent of added acid would induce. In some instances the difference was enormous. Now it is generally recognized that it is not only safer and more logical but easier to adjust on a pH basis. Just as the old procedure was carried out when adjustments were made to "the neutral point of phenolphthalein" so adjustments may be carried out on the new basis with only this difference—that an indicator is chosen which brings the "zero point" at the

desired pH, as phenolphthalein brought it to the alkaline point of about pH 8.4. Having thus attained the desired reaction it is left there without the addition of a certain "per cent of acid" which we now know sent the reaction into unknown regions.

At first the following final reactions were used; for nutrient agar pH 6.7-7.0; for lactose broth, pH 6.8-7.0; and for Endo's agar, pH 7.8-8.0. Later on the final reaction of lactose broth was changed to pH 8.0. In the latter part of 1920 we went into this subject in more detail and being unable to find in the literature available to us any specific hydrogen-ion concentrations for the above media in use in other laboratories we decided to send a letter of inquiry to some of the laboratories in the United States. The information contained in nineteen answers to this letter is summarized in table 1.

REACTION OF LACTOSE BROTH

On referring to the latest (fourth) edition of *Standard Methods of Water Analysis* (1920) we find the following statement on page 95:

d. Sugar Broths

The reaction of sugar broths shall be a faint pink with phenol red or, if on titration with phenolphthalein the reaction is not already between neutral and +1, adjust to neutral.

On page 94 of the same book in paragraph four, under the heading bb, we find the sentence:

The reaction of media containing sugar shall be neutral to phenolphthalein.

The above directions for adjusting the reaction of a sugar broth are conflicting in two respects and lead a man to ask:

1. Shall the reaction of a sugar broth always be made neutral as the latter of the above two quotations implies or shall it be left between neutral and +1 according to the former quotation?

2. Shall the reaction of a sugar broth be adjusted to a faint pink to P. R.⁵ or to the neutral point of P.⁶

According to the first paragraph under heading bb on page 94 of the above book we are advised that the adjustment of the reaction of a medium may be made more accurate if the H. I. C.⁷ is determined by means of the P. R. method yet in paragraph four under the

⁵ P. R. = phenol red.

⁶ P. = phenolphthalein.

⁷ H. I. C. = hydrogen-ion concentration.

TABLE I

Hydrogen-ion concentrations of media in use in various laboratories

NAME OF LABORATORY	AUTHORITY	REACTIONS OF MEDIA		
		Nutrient agar	Lactose broth	Endo's agar
Bureau of Laboratories, Department of Health, City of New York	Wm. H. Park	pH 6.4	pH 6.4- 6.8	pH 8.2
State Water Survey Division, Urbana, Ill.	M. C. Perry	pH 6.6	pH 7.9	pH 6.9
Water Laboratory, State Department of Health, Albany, N. Y.	L. M. Wachter	pH 6.8	pH 7.6- 8.0	pH 7.0
Iowa State College, Department of Bacteriology and Hygiene	Max Levine	pH 6.8	pH 7.0	pH 7.4
United States Department of Agriculture, Bureau of Chemistry, Microbiological Laboratory	Stewart A. Koser	pH 6.4- 6.8	pH 7.2- 7.4	
Treasury Department, Hygienic Laboratory, Public Health Service	M. W. McCoy	pH 7.6	pH 6.6- 7.0	
Department of Hygiene and Bacteriology, The University of Chicago			pH 7.6	pH 7.6
Bacteriological Laboratory Sheffield Scientific School, Yale University	Leo F. Rettger	pH 6.8	pH 7.0	
Municipal Water Works, Springfield, Mass.	Herbert F. Salmond	+1	+5	
Filtration Division Laboratory, Baltimore, Md.	J. R. Bayliss	"Just pink with phenol red"		
Laboratories for the State Board of Health, State University of Iowa, Iowa City, Iowa	Jack J. Hinman, Jr.	"Faint pink with phenol red"		
University of Illinois, Division of Bacteriology	F. W. Tanner	True neutrality, brom thymol blue		
University of Michigan, Hygienic Laboratory	F. E. Novy	pH 7.4 For general class work		

TABLE 1—Continued

NAME OF LABORATORY	AUTHORITY	REACTIONS OF MEDIA		
		Nutrient agar	Lactose broth	Endo's agar
Mt. Prospect Laboratory, Brooklyn, N. Y.	Frank E. Hale	Those given in 1912 edition of Standard Methods of Water Analysis		
State Board of Health, Vermont	B. H. Stone	Difco dehydrated media		
University of Pennsylvania, School of Public Hygiene	A. C. Abbott	pH 7.6 for all media for ordinary standard work		
Filtration Division, Bureau of Water, Pittsburg, Pa.	W. U. C. Baton	Reactions not given Adjustments to phenolphthalein titrations		
Minnesota State Board of Health, St. Paul, Minn.	H. A. Whittaker	Recently changed to adjustment by H-ion concentration. Reactions not available		
University of Missouri, Columbia, Mo.	Mazyck P. Ravenel	About to adopt adjustment by H-ion concentration		

same heading we are instructed to make the reaction of media containing sugar neutral to P. Why should we be advised to use the more accurate method of determining the H. I. C. and to adjust the reaction of a sugar broth to "a faint pink with phenol red or, if on titration with phenolphthalein the reaction is not already between neutral and +1, adjust to neutral," when on the opposite page of the book there appears the positive statement: "The reaction of media containing sugar shall be neutral to phenolphthalein."

If the more accurate method of determining the H. I. C. is to be substituted for the titration with P. and if "the reaction of media containing sugar shall be neutral to phenolphthalein," why not adjust sugar broths to a H. I. C. of 8.0, the neutral point of P. instead of 7.0 which is the point of true neutrality or the H. I. C. of pure water?

The following extract is taken from a report on the Chart for Identification of Bacterial Species by the Committee of the Society of American Bacteriologists (1918):

It is recommended, however, that instead of using phenolphthalein in adjusting the reaction of these media the simpler and more accurate procedure be adopted of adjusting to the neutral point of brom thymol blue.* Bring

* 0.04-per cent di bromo thymol sulphophthalein in 95 per cent alcohol.

the media to such an acidity as to turn this indicator a distinct grass-green (neither yellow green nor blue green). This color indicates approximately "true neutrality," i.e., a hydrogen-ion concentration between pH = 6.6 and pH = 7.4, a variation which seems to have no appreciable effect on bacterial activities. Another equally satisfactory method of adjusting media to this hydrogen-ion concentration is to bring them to such an acidity as to cause the first faint trace of permanent pink to appear with phenol red.⁹

In the same report the Committee recommends that the reactions of beef extract broth, beef extract agar and gelatine, and sugar broths all be adjusted to "true neutrality," i.e., to a H. I. C. between pH -6.6 and pH-7.4.

In table 1 we find that the reactions of lactose broth vary from pH 6.4 to 8.0, indicating that in some of the laboratories the reaction is adjusted to the neutral point of P., pH 8.0, in others it is adjusted to within a range of pH 6.6 to 7.4 with either P. R. or B. T. B.¹⁰ as the indicator, and in the remainder it is adjusted to an intermediate point between pH 7.4 and 8.0. This wide range in the reaction of lactose broth is undoubtedly due to the different reactions recommended in the report of the Committee of the Society of American Bacteriologists (1918) and in the *Standard Methods of Water Analysis* (1920).

The dehydrated lactose broth prepared by the Digestive Ferments Company is adjusted to a neutral reaction and after sterilization for 20 minutes at 15 pounds pressure it is supposed to have a H. I. C. of pH 8.0. The neutral reaction must refer to neutrality to P. rather than to true neutrality.

At the present time we are preparing lactose broth according to the directions on page 95 of *Standard Methods* (1920), using Bacto-beef and Bacto-peptone. The following reactions were obtained during the preparation of a typical 3 liter batch:

Composition: distilled water (pH 6.4), 3 liters; Bacto-peptone, 15 grams; Bacto-beef, 150 grams; Bacto-lactose, 15 grams.

First reaction

To phenolphthalein.....+0.8¹¹ To brom thymol blue pH 6.4
24.5 cc. of N/1 NaOH were then added:

⁹ 0.02-per cent phenol sulphonphthalein in 95 per cent alcohol.

¹⁰ B. T. B. = Brom thymol blue.

¹¹ All reactions to phenolphthalein determined as given under "bb," page 94, "Standard Methods." (1920).

Second reaction prior to sterilization

To phenolphthalein.....	+0.5
To brom thymol blue.....	pH 7.0
To phenol red.....	pH 7.0

Either reaction to P. comes within the limits of "between neutral and +1," but only after the addition of the sodium hydrate does the H. I. C. come to that of "true neutrality," pH 7.0.

If the final reaction of lactose broth, prepared from the above ingredients, be changed from pH 7.0 to pH 8.0 (neutral to P.) we find that nearly twice as much sodium hydrate must be added in order to obtain the latter H. I. C., i.e., to the above batch about 47 cc. of N/1 NaOH would have been added instead of 24.5 cc.

Using Liebig's beef extract (3 grams per liter) in the place of the Bacto-beef in the formula previously given for lactose broth, the following reactions were obtained during the preparation of a typical 4 liter batch:

First reaction

To phenolphthalein.....	+0.7
To brom thymol blue.....	pH 6.4

10.5 cc. of N/1 NaOH were then added:

Second reaction, prior to sterilization

To phenolphthalein.....	+0.45
To brom thymol blue.....	pH 7.0
To phenol red.....	pH 7.0

While the first reaction of this batch, pH 6.4, was the same as that of the previously described typical batch prepared with Bacto-beef, we found that only 10.5 cc. of N/1 NaOH were required for the adjustment of the reaction to pH 7.0 as compared with 24.5 cc. for the Bacto-beef batch. During the preparation of 130 batches of lactose broth, using Bacto-peptone and Liebig's beef extract, we found that the average volume of N/1 NaOH required for the adjustments of the reactions to pH 6.9 to 7.0 varied from 1.5 to 2.1 cc. per liter. On substituting Bacto-beef for Liebig's beef extract but continuing to adjust the reaction to the same H. I. C. we found that the average volume of N/1 NaOH increased to 8.2 to 10 cc. per liter.

Fennel and Fisher (1919) have written as follows on the variation in peptones:

There is a wide variation in reactions among the peptones in common use; there is even a variation between batches of the same brand.

Of several samples titrated in a 1 per cent solution, we find Witte, pH 7, Armour's pH 6.6, Difco pH 7.3, and Fairchild's pH 4.9. These samples titrated cold, with phenolphthalein as indicator, yield the following: Witte, 0.4 per cent acid, Armour, 0.7 per cent acid, Difco, 0.3 per cent acid, and Fairchild, 1.25 per cent acid.

In order to determine the effect of different brands of peptone on the H. I. C. of broth, liter batches were prepared using 5 grams each of five brands of peptone and 3 grams of Liebig's beef extract per liter of distilled water, the reaction of the latter being pH 6.4 to brom thymol blue. After the peptones had dissolved by heating to 65°C. the broths were filtered and the reactions determined both in terms of H. I. C. and the phenolphthalein titration.

TABLE 2
The reactions of beef broth with five different brands of peptone

BRAND OF PEPTONE	H. I. C. EXPRESSED IN pH	REACTION TO PHENOLPHTHALEIN 5 cc. TO 45 cc. DISTILLED WATER	
	2 cc. medium plus 8 cc. water 29°C.	Hot	Cold 29°C.
Bacto-peptone.....	6.6 B. T. B.	+0.7	+0.45
Witte.....	6.4 B. T. B.	+0.6	+0.50
Merck.....	5.8 M. R.	+0.85	+0.60
Fairchild.....	5.7 M. R.	+1.05	+0.80
Stearns.....	5.6 M. R.	+1.15	+0.90

Three of the above broths were found to have reactions to P., titrated hot, of less than +1, in other words their reactions ranged "between neutral and +1," so that according to the directions in "Standard Methods" they would be left unchanged. According to these examples and the ones previously given, it is seen that the H. I. C. of lactose broth may vary between pH 5.8 and 7.0 when the reaction falls "between neutral and +1," but if the reaction is adjusted to "neutral to phenolphthalein" it will be found that the H. I. C. will jump to pH 8.0 or 8.2. This means then that, according to the directions given in the "Standard Methods," we may use lactose broth varying in H. I. C. between pH 5.8 and 8.2, depending upon the brand of peptone and whether or not we adjust the broth to "neutral to phenolphthalein." As determined at room temperature (29°C.) the reactions to phenolphthalein were all less than when determined hot and they were also "between neutral and +1."

While we always determine and adjust reactions by means of color standards we have tried the adjustment of the reaction of lactose broth by titration to "a faint pink with phenol red," with the following results:

To 5 cc. of broth added 5 cc. of distilled water and 5 drops of P. R. indicator (0.04 per cent Medalia's solution). 0.8 cc. of N/20 NaOH were required to produce a "a faint pink." Added 32 cc. of N/1 NaOH to the 4 liter batch and on again titrating obtained a "faint pink" color. With B. T. B. a pH of 6.8 was obtained. After the addition of 4 cc. more of N/1 NaOH a pH of 7.0 was obtained with B. T. B. In order to catch the development of the "faint pink" color a second dish, containing the same amounts of broth, distilled water and indicator, was used alongside the dish in which the titration was made. While we think that by using sufficient care the reaction of broth or sugar may be adjusted by this qualitative method to fall within the range of pH 6.6 to 7.4 we feel that the method is open to the same objections which have been made against the titration with P. to "a faint but distinct pink color" for the end point. In order to give a more precise description of the latter end point the use of a color top was recommended in the 1912 edition of the *Standard Methods*. A very good colored plate to illustrate the end points in the P. titration may be found on page 152 of Erye's *Bacteriological Technique*, second edition.

In some of the answers received to our letter of inquiry this qualitative method of adjusting the reaction of broth and sugar was severely criticised, for example:

The same objection applies to the end point with phenol red as to the end point with phenolphthalein or any other indicator, that is, two observers may get entirely different results, owing to the different interpretations of the term, "a faint pink."¹²

It seems to me that the directions given in the 1920 *Standard Methods for Water Analysis* for using phenol red are not good at all. The first color change of phenol red that the average worker would notice would be at least pH 7.4 or 7.6. The first noticeable color change of phenolphthalein in a medium, is at least pH 8.2 or more, depending on the worker.¹³

To correspond to the color top we have a color chart first published in Clark's (1920) book, which gives the colors of Clark and Lubs'

¹² Private communication from Stephen DeM. Gage, Chemist and Sanitary Engineer, Rhode Island State Board of Health, Providence, R. I.

¹³ Private communication from Bertha van H. Anthony, M. D., Bureau of Laboratories, Dept. of Health, City of New York.

indicators in solutions of known pH but a man must have had considerable practice with it to obtain satisfactory results.

In adjusting the reaction of lactose broth by the addition of N/1 NaOH the amount first added from the titration calculation seldom brings the H. I. C. up to the desired point and it is necessary to add a few more cubic centimeters even though the exact relation between the N/20 and N/1 NaOH solutions are known. Hurwitz, Meyer, and Ostenberg (1916) recommended that a curve be plotted from a series of titrations to enable a correction to be easily made and thus eliminate a second adjustment. The reason for this difference is that in media, there are organic substances, called "buffers," which combine with some of the sodium hydroxide and thus prevent it from neutralizing the acid. Cox and Wood (1920) state:

The presence or absence of buffering substances will have a tremendous influence on the final reaction of media adjusted according to the established method of making neutral to phenolphthalein and then adjusting to 1 per cent, 2 per cent, etc., acid on the basis of the preliminary titration. An unbuffered solution, adjusted to 1 per cent acid, would have a true reaction of very acid pH value around 5.0, while a buffered medium solution adjusted to 1 per cent acid to phenolphthalein might still be as alkaline as 7.8 or 8.0.

According to Foster and Randall (1921):

Broth (beef infusion, beef extract, bacto-beef) adjusted to pH values ranging from 5.0 to 9.0 undergoes a change in hydrogen-ion concentration upon autoclaving. This change is most marked in media adjusted in the alkaline range (7.8-9.0), less great in the acid range (5.0-6.2), and is usually inappreciable in the neutral range of (6.6-7.4). The maximum change is about 0.4 pH and in the majority of cases is not over 0.2 pH.

The change is usually an increased acidity (decrease in pH). Decreases in acidity have been observed in a few instances but these are exceptional.

Autoclaved broth undergoes changes in hydrogen-ion concentration upon standing; the degree of change is not influenced by the environmental temperature within the limits, 10°C. (ice chest) and 37°C. (incubator).

The change upon standing is almost invariably in the direction of an increase in acidity.

The media prepared in the Miraflores laboratory are sterilized in an electrically heated No. 4B Bramhall and Deane autoclave of the horizontal cylindrical type, 27½ inches long by 24½ inches in diameter, inside measurements. With this type of autoclave and holding the broth in flasks at 17 pounds pressure for 20 minutes, the total lapse of time from the insertion of the medium to its removal averages 1 hour. In the Mt. Hope and Agua Clara laboratories

there are used electrically heated autoclaves of the vertical cylindrical type, 24 inches high by 11 inches in diameter, inside measurements. With this type of autoclave and holding the broth in flasks at 17 pounds pressure for 20 minutes, the total lapse of time from the insertion of the medium to its removal averages 60-80 minutes. There is an additional sterilization for 80 minutes at 100°C. after the addition of the sterile lactose solution and the tubing of the broth. The reactions of batches of lactose broth, adjusted to either pH 6.9, 7.0, or 7.1 before sterilization were not appreciably changed by the autoclaving.

In reference to the change in lactose broth stored in an ordinary large size refrigerator of the house type we have found at the end of seven days that the H. I. C. has changed from pH 7.0 to 6.8 or 6.9. In the Miraflores laboratory lactose broth is made up in 4 liter batches at intervals of three or four days so it is seldom that tubes of it are stored in the refrigerator for more than four days at the end of which time no appreciable change in the H. I. C. has taken place. If broth is to be stored in the refrigerator of a laboratory for more than seven days allowance should be made for a change in the H. I. C.

We have found that the final H-ion concentrations of several tubes of lactose broth filled from the same batch always agree very closely.

Wagner and Monfort (1921) in their discussion on lactose broth raise the following point:

The reaction, adjusted to neutrality prior to autoclaving, is greatly modified by the alkalinity of natural waters tested; the pH values of 6.6 to 7.4 rarely prevail in fermentation tubes as incubated.

With the waters available to us, ranging in pH values from 4.9 to 8.1, we have not found this to be the case for the pH values of waters mixed with the broth in 1 and 10 cc. fermentation tubes have neither fallen below pH 6.8 nor exceeded pH 7.0. 10 cc. and 25 cc. of broth, respectively, were used in the Durham fermentation tubes to which 1 cc. and 10 cc. of water are added. The concentration of lactose in the mixture of 10 cc. of water and 25 cc. of broth was 0.33 per cent, while in the mixture of 1 cc. of water and 10 cc. of broth it was 0.42 per cent. Table 3 contains the data relating to this point.

In determining the H. I. C. of lactose broth by means of P. R. and the standards put up by Hynson, Westcott, and Dunning,

10 cc. of the broth is placed in a test tube and 1 cc. of a 0.01 per cent aqueous solution of the indicator added. If the indicator is added to the warm broth and the color compared with the above standards we find that the warm broth throws the color of the mix-

TABLE 3

The change in hydrogen-ion concentration of lactose broth by the addition of waters of various alkalinities

KIND OF WATER	ALKALINITY, PARTS PER MILLION		HYDROGEN-ION CONCENTRATIONS EXPRESSED IN pH		
	Erythro- sine	Carbonate (CO ₂)	Water	Lactose broth plus	
				1 cc. water	10 cc. water
Chagres River, raw water supply for Miraflores Purification Plant.....	54.1		7.2	6.9	7.0
Agua Clara reservoir, raw water supply for Agua Clara Purifica- cation Plant.....	25.4		6.9	6.9	6.9
Settled water from above Plant..	1.0		4.9*	6.8	6.9
Filtered water from above Plant.	20.4		7.3	6.9	6.9
Rio Grande reservoir.....	64.3	4.8	7.6	6.9	6.9
Ground water, Corozal road, Canal Zone.....	113.2		7.5	6.9	6.9
Sea water in swimming pool, Colon, R. de P.....	132.6		7.7†	7.0	6.9
Santa Ana spring water, Costa Rica.....	377.6	26.4	7.6	7.0	7.0
Well water, Barranquilla, Colom- bia.....	502.1	68.5	8.1†	7.0	7.0
Ditto.....	167.3	14.4	7.8†	7.0	6.9

Indicators: * = methyl red; † = phenol red; all other determinations, brom thymol blue. The pH value of the lactose broth in all the tubes was 6.9. All hydrogen-ion concentrations were determined by diluting 2 cc. of the contents of the broth tube with 8 cc. of distilled water with a pH value of 6.4.

ture off shade a little. Therefore when determining the H. I. C. of broth in this manner we recommend that it be cooled to room temperature before the P. R. is added. In determining the H. I. C. by means of B. T. B. and the standards prepared after Medalia, 2 cc. of the broth are added to 8 cc. of distilled water which has been kept at room temperature, i.e., about 29°C., and then 0.8 cc. of the indicator. The shade of this mixture compares very closely with that of the standard color, the 8 cc. of distilled water serving to cool the broth.

The question is apt to arise in the mind of a man who has not had the opportunity to go into all the details of hydrogen-ion work that an error is introduced by the dilution of 2 cc. of lactose broth or nutrient agar with 8 cc. of distilled water which has a H. I. C. different from that of the former. In reference to this point Foster and Randall (1921) have written:

Preliminary tests showed that with broth and cultures it was possible to dilute 1 cc. of the material with 4 cc. of distilled water without altering the hydrogen-ion concentration.

Freshly boiled and cooled distilled water was used for diluting as preliminary tests had shown that unboiled water gave slightly lower pH readings. The pH of the water itself was usually found to rise from 4.8 to 6.8 upon boiling, probably due to the liberation of carbon dioxide.

The distilled water used in the Miraflores laboratory is produced by a Barnstead automatic type E still, electrically heated, and as removed from the storage bottle has an average pH of 6.4. With lactose broth and nutrient agar we have determined the H. I. C. by adding in one case 2 cc. of the medium to 8 cc. of distilled water and in another case by using 10 cc. of the undiluted medium and comparing the colors with the standards prepared after Medalia. No appreciable difference was found in the hydrogen-ion concentrations of the diluted and undiluted media, the reaction of which had been adjusted to pH 6.9 to 7.2.

Figure 1 after chart 8 in the paper by Cox and Wood (1920):

illustrates the dissociation of the hydrogen-ions in a medium at varying temperatures. The plain extract broth medium used here has a pH of 8.4 at room temperature (20°C.) and a pH of 7.4 at 70°C., and the varying pH values indicated at the intervening temperatures. It is necessary to adjust titrations so that the end point will be the pH desired at the temperature at which the medium will actually be used. This can be done by the use of a constant temperature bath and by adjusting the reaction of the medium in preparation

at exactly the required temperature. It must be remembered that pH 7.0 is the true neutral point only at room temperature (20°C.), variations in temperature from this value alter our total pH scale, hence it is essential to determine and include, in our definitions of optimum pH values, the temperature.

From the above we judge that in adjusting the reaction of a batch of lactose broth we should bring it to a temperature of 37.5°C., at which it will be incubated later on when in use, before determining the H. I. C. and adding the correct amount of N/1 NaOH. The 2 cc. portions of broth removed from the batch should also be diluted

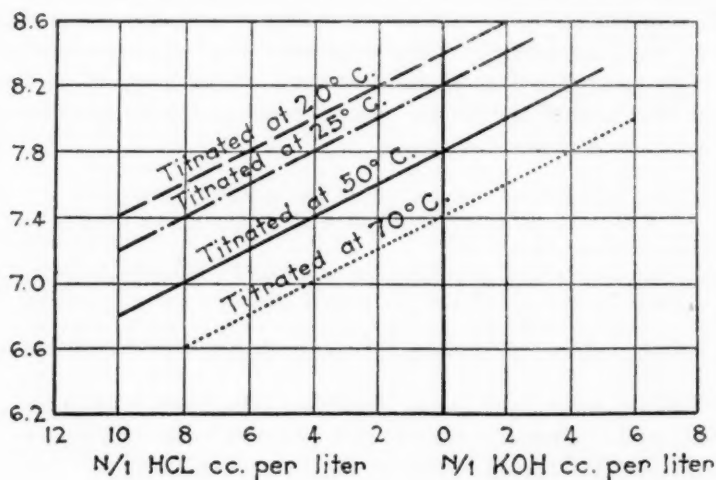


FIG. 1. COMPARATIVE TITRATIONS OF THE SAME MEDIA AT DIFFERENT TEMPERATURES

with distilled water of a temperature of 37.5°C. In general the temperature of a batch of broth in the Miraflores laboratory at the time of the addition of normal alkali to bring the reaction to pH 7.0 averages 31.5°C. while the temperature of the mixture of 2 cc. of broth, 8 cc. of distilled water and 0.8 cc. of indicator averages 29.5°C. On incubating tubes of broth adjusted to pH 7.0 under these conditions at 37.5°C. for 24 hours we found that the H. I. C. was increased to 7.2 and remained at this point after a second period of 24 hours or a total of 48 hours. It appears, therefore, that the broth should have been originally adjusted to pH 6.8 in order to insure a H. I. C. of 7.0 during the early part of its incubation

but as the addition of waters of different H-ion concentrations introduces another variable factor it is hardly worth while to make a correction for the difference in temperature at the time of adjustment of the reaction or to make use of a constant temperature bath.

For keeping a permanent record of the composition and reactions of the batches of lactose broth prepared in the laboratory we employ a note book measuring 6 inches long by $3\frac{1}{4}$ inches wide. On the inside of the front cover there is pasted the typewritten directions for the preparation of the broth which are followed by the laboratory helper until they are superseded by a new set of directions in case of changes in the composition of the broth. On the first page of the book facing the inside of the front cover there is pasted a second typewritten sheet containing the various entries to be made by the laboratory helper on the blank pages of the book before the batches of broth are prepared. Opposite some of these entries the bacteriologist records the reactions and at the bottom of the pages signs his initials to indicate that the composition, preparation and final reaction of the broth are correct. Table 4 is a copy of a page in this note book.

TABLE 4
Specimen page of lactose broth record book
Batch 9. Lactose broth. 4/30/21

	grams
Weight of can.....	1500
Weight of distilled water.....	4000
Weight of bacto-beef.....	200
Weight of bacto-peptone.....	20
Total.....	5700
40 cc. N/1 NaOH added	
Reaction, pH 7.0 with B. T. B.	
Reaction before sterilization.....	pH 7.0 B. T. B.
Reaction after sterilization.....	pH 7.0 B. T. B.
Weight of bacto-lactose	20 grams
Chemists O.K., H. S.	

On the inside of the cover of the daily note book, in which the bacteriological analyses of the daily samples of water are recorded, there is pasted a sheet on which entries are made to show between what dates the various batches of lactose broth are used. There is also pasted on the inside of this cover a sheet which shows the composition and the method of preparation of the broth used during the period covered by the notebook. If a change is made in the composition of the broth during this period the changed formula is

entered on this same sheet. In this manner a permanent record is kept which eliminates the vagaries of the memory of the man in charge of the laboratory and which enables a man going over the notebooks a few months or years later to obtain definite information concerning the broth used during any period.

In conclusion it appears desirable to decide whether lactose broth is to be adjusted to "neutral to phenolphthalein" or to "true neutrality," thus eliminating the wide range of H. I. C. resulting from the use of a reaction "between neutral and +1." If the reaction is adjusted qualitatively, that is, by means of a certain color tint of an indicator, we may expect to have the following ranges in H. I. C.:

Brom thymol blue or phenol red	pH 6.6 to 7.6
Phenolphthalein	pH 8.0 to 9.0

We recommend that the reaction be adjusted by means of color standards, prepared either with B. T. B. or P. R. as the indicator, and that the range of H. I. C. be limited to 6.8 to 7.2. We also recommend the same range of reaction for nutrient broth.

REACTION OF NUTRIENT AGAR

On referring to the latest edition of *Standard Methods* (1920) we find the following statement on page 96:

f. Nutrient agar

3. Make up lost weight and adjust the reaction to a faint pink with phenol red, or if the phenolphthalein titration is used, and the reaction is not already between +0.5 and +1, adjust to +1.

In the *Standard Methods for the Bacteriological Examination of Milk* (1921) we find on page 8 the following statement under the heading of "Reaction":

Inasmuch as the range of H-ion concentration recommended for water analysis is pH = 6.8 to 8.4, it is permissible, if desired, to use a single agar for both purposes (milk and water analyses—authors' insert) with a reaction of pH = 6.8 to 7.0. If Witte's peptone is used in the above formula, this will ordinarily be the reaction without adjustment.

What is meant by the clause, "Inasmuch as the range of H-ion concentration recommended for water analysis is pH 6.8 to 8.4?" Does the Committee mean that for water analysis nutrient agar may be adjusted to a reaction varying between these limits? While this interpretation does not appear reasonable on second thought, yet it is entirely plausible for *agar* is the only medium under dis-

cussion. A reference in the above paragraph refers to page 93 of *Standard Methods*, a. Adjustment of Reaction.

aa. Phenol red method for adjustment to a hydrogen-ion concentration of pH = 6.8-8.4.

This leads us to inquire why this range, when on the following pages the only reaction referred to in the adjustment of the media is that of faint pink with P. R. As previously quoted the Committee of the Society of American Bacteriologists recommends that the reaction of beef extract agar be adjusted to the neutral point of B. T. B. or to the first faint trace of permanent pink with P. R., which colors indicate approximately "true neutrality," i.e., a H. I. C. between pH, 6.6 to 7.4. If the range of pH 6.8 to 8.4 in the *Standard Methods* for both milk and water analysis is a misprint for 6.8 to 7.4 and the latter is substituted in the first sentence of the paragraph quoted from the *Standard Methods* of milk analysis, the meaning of the paragraph becomes clearer. If it is not a misprint we believe that pH 8.4 should be changed to pH 7.4, because all of the reactions adjusted to a faint pink with P. R. would come within the range of pH to 7.4 if carefully taken.

Perhaps the range of pH 6.8 to 8.4 was used because this covers the entire range of P. R. If so, did the Committee think that one could not come closer to a "faint pink" than the red of pH 8.4 or the yellow shade of pH 6.6? If so what is the improvement over the indefinite end point of the phenolphthalein titration?

Whatever may be the correct interpretation of the sentence under discussion the Committee on the *Standard Methods* of milk analysis has made it clear that nutrient agar with a H. I. C. of 6.8 to 7.0 is suitable for both milk and water analysis. The Committee of the Society of American Bacteriologists recommends that the reaction of beef extract agar be adjusted to "true neutrality," so that for this medium the two Committees are in close agreement.

In table 1 we find that, while the reactions of nutrient agar vary from pH 6.4 to 7.6, the majority of the laboratories keep within the limits of pH 6.4 to 6.8, slightly lower than the range recommended above. The dehydrated nutrient agar prepared by the Digestive Ferments Company is adjusted to a reaction between +0.5 and +1.0 and after sterilization for 20 minutes at 15 lbs. pressure it is supposed to have a H. I. C. of 6.5.

At the present time we are preparing nutrient agar according to the directions on page 96 of *Standard Methods* (1920). The fol-

lowing reactions were obtained during the preparation of a typical 3 liter batch: Composition; grams; distilled water (pH 6.4), 3000; dried bacto-agar, 36; bacto-peptone, 15; Liebig's beef extract, 9.

First reaction

To phenolphthalein.....+0.4
To brom thymol blue.....pH 6.4
7 cc. of N/1 NaOH were then added.

Second reaction

To phenolphthalein.....+0.3
To brom thymol blue.....pH 6.9
1 cc. of N/1 NaOH was then added.

Third reaction

To phenolphthalein.....+0.3
To brom thymol blue.....pH 7.0
To phenol red.....pH 7.0

The final H. I. C. of the agar is that of "true neutrality" while the reaction to phenolphthalein is +0.3. According to the directions in *Standard Methods* (1920) for adjusting the reaction with the latter indicator, the addition of N/1 HCl is necessary in order to bring the reaction to +1, because the first reaction was not between +0.5 and +1. In order to show what happens under such conditions we adjusted the reaction of a batch of agar with an initial reaction of +0.4 to P. to a final reaction of +1, which brought the H. I. C. to 4.9 with M. R.

Plates were made from this agar and compared with some made from the other portion of the batch which was adjusted to pH 7.0. The numbers of colonies which developed on the kinds of agar during 24 hours incubation at 37.5°C. were as follows:

WATER	COLONIES ON AGAR	
	pH 7.0	pH 4.9
Raw.....	300	4
Raw.....	250	2
Aerated.....	350	2
Aerated.....	375	8
Settled.....	230	2
Settled.....	250	2
Settled.....	375	6
Settled.....	190	2

It is seen that the more acid agar inhibited the growth of the bacteria. It would have been preferable, at least in our laboratory, to have left the reaction of this batch of agar at +0.4 to P. or at pH 6.4 instead of changing it to +1. The appearance of the tubed pH 4.9 agar after two days was hard but on inverting and shaking a tube the agar was found to be slushy. Another batch of nutrient agar, final reaction pH 4.9, after storage in the refrigerator for 14 days, was so slushy that plates could not be made from it.

The reactions of 24 batches of nutrient agar, prepared prior to the date on which we started to take the H. I. C., averaged +0.5 to P., using the end point of the color top previously described under lactose broth. Under this condition it was thought best to leave the reaction alone and not add any acid to the agar. After adjustment of the reaction according to the H. I. C. was started, the use of the same materials being continued, it was found necessary to add 2 cc. of N/1 NaOH per liter of agar to obtain a final pH 6.9 to 7.0. In general it may be said that the H. I. C. of the agar with a final reaction of +0.5 to P. was pH 6.6 so that when we changed the final reaction of this medium to pH 6.9 or 7.0 we did not notice any difference in the counts. At the present time we find that the first or "native" reaction of nutrient agar, of the composition previously given, averages pH 6.4 to 6.6 and that in general 2.5 to 3 cc. of N/1 NaOH per liter must be added to give a final H. I. C. of 6.9 to 7.1 with B. T. B.

One cannot be certain that a reaction to P. will always have a corresponding fixed H. I. C. equivalent. For example we have found at times that a batch of agar with a reaction of +0.3 would have a pH of 6.9 or 7.0; again that a reaction of +0.5 would correspond to a pH of 6.6 or less (at this time we had no standard lower than 6.6); and at other times that a reaction of +0.6 would correspond to a pH of 6.9.

Fennel and Fisher (1919) state:

There is no constant interrelationship between pH readings and phenolphthalein titrations, except in a case where a definite relationship has been established, in a medium of absolutely standard construction, using distilled water, the same batch of meat extract and peptone. Any change in technic changes the relationship between the two systems of titration; as a matter of fact, the pH is so satisfactory and practical, that this relationship is only of academic interest.

While we always determine and adjust the reaction of nutrient agar by means of color standards we have tried the adjustment of the reaction by titration with B. T. B. to a "distinct grass green," with the following results:

To 5 cc. of distilled water added 5 cc. of the agar and 5 drops of B. T. B. (0.02 per cent) and titrated in a casserole with N/20 NaOH. According to this titration we added 8 cc. of N/1 NaOH to the 4 liter batch and obtained a reaction of pH 6.8. The same objections apply to this qualitative method of adjusting the reaction of nutrient agar as were given under lactose broth. A further addition of 4.3 cc. of N/7 NaOH was made to the above batch in order to obtain a final pH 6.9.

The nutrient agar prepared in the Miraflores laboratory for the laboratories of the three purification plants is sterilized in the large autoclave described under lactose broth and is held in it for an average period of one hour from the start to the finish of the sterilization. The reactions of batches of nutrient agar, adjusted to either pH 6.9, 7.0 or 7.1 before sterilization were not appreciably changed by the autoclaving.

Tubes of nutrient agar, pH 6.9 to 7.1, did not show any appreciable change in H. I. C. when stored for 15 days in the same refrigerator mentioned under lactose broth. In the Miraflores laboratory nutrient agar is made up in 4 liter batches at intervals of 4 to 5 days so it is seldom that tubes of it are stored in the refrigerator for more than 4 days at the end of which time no appreciable change in the H. I. C. has taken place. The nutrient agar for the Mt. Hope and Agua Clara laboratories is prepared in the Miraflores laboratory and shipped to them in tubes ready for use. All the agar is prepared under the supervision of the same bacteriologist and the reaction of each batch is adjusted to the same H. I. C. in order to eliminate the variations which would creep in if it were prepared in three different laboratories.

Fennel and Fisher (1919) make the statement that:

Agar mediums are best adjusted in the broth stage, and the agar added as the last step. Agar is, for all practical purposes, neutral in reaction, and does not change the pH of the broth. If this should not be convenient, the agar may be melted and titrated hot. In comparing the colors with agar it is best to wait until the agar has set before concluding that the colors are identical. It is a simple matter to send this tubed specimen, with indicator in it, along with the batch of mediums, through the sterilization process to check the reaction after sterilization.

In reference to the last sentence in this quotation we have tried sending two tubes of nutrient agar through the autoclave, 10 cc. each, to one of which 0.8 cc. of 0.04 per cent P. R. had been added and to the other of which 0.8 cc. of 0.02 per cent B. T. B. had been added. The tube of agar containing the P. R. gave a reaction of pH 7.1 and that containing the B. T. B. gave a reaction of pH 6.9 with the latter indicator. According to this experiment we believe it best to obtain the final reaction on tubes of agar which have gone through the autoclave without any added indicator.

We have experienced no difficulties in adjusting the reaction of broth in which agar has been dissolved and as the final reaction must be taken on the nutrient agar ready for use we think it best to make all the H-ion determinations on the broth containing the agar. We like the color shades produced by B. T. B. better than those produced by P. R. when color standards prepared after Medalia are used in the comparator block which will be described in a later section of this paper. In this connection Medalia (1920) observed that:

The phenol red does not make as clear cut a range, as easily differentiated at pH 0.2 intervals, as does brom thymol blue and is not really necessary for the titration of culture media which as a rule are neutral, or thereabouts.

We also prefer to determine the H. I. C. of nutrient agar by means of color standards prepared after Medalia rather than by means of the set of color standards prepared by Hynson, Westcott and Dunning as we believe that the color of the unknown can be matched more closely with that of the standards.

In determining the H. I. C. of nutrient agar by means of B. T. B. and standards prepared after Medalia 2 cc. of the agar are added to 8 cc. of distilled water, which has been kept at room temperature, i.e., about 29.5°C., and then 0.8 cc. of the indicator, 0.02 per cent solution. The color of the nutrient agar tube may then be matched immediately against the standards or allowed to stand five or ten minutes, for the dilute agar will not solidify, but we have observed that if allowed to stand for 20 minutes or over the color of the unknown will grow slightly darker. In the *Standard Methods for the Bacteriological Examination of Milk* (1921), the use of distilled water of a temperature of 30 to 40°C. is advised but we do not see the necessity of using water of this temperature and believe it is preferable to have the temperatures of the unknown and the standards

about the same, that is, at the temperature of the room in which the latter are kept.

In determining the H. I. C. of nutrient agar by means of P. R. and the standards put up by Hynson, Westcott and Dunning 10 cc. of agar is placed in a test tube and 1 cc. of the indicator added (0.01 per cent aqueous solution). In this case the agar should be cooled to room temperature before the colors are compared as we have observed that the pH 7.0 of a tube of hot agar increased to pH 7.1 on cooling. Hurwitz, Meyer, and Ostenberg (1916) advise that:

Readings should be made on the solidified medium at a constant room temperature, since the hydrogen-ion concentration changes with the temperature.

A permanent record of the composition and reactions of the batches of nutrient agar prepared in the Miraflores laboratory is kept in the same manner as described under lactose broth in a separate note book. Table 5 is a copy of a page of this book.

TABLE 5
Specimen page of nutrient Agar Record Book
Batch 4. Nutrient agar. 4/16/21

	grams
Weight of can.....	1182
Weight of distilled water.....	4000
Weight of bacto-agar.....	48
Weight of bacto-peptone.....	20
Weight of beef extract.....	12
Total.....	5262

10 cc. N/1 NaOH added.

Reaction, pH 7.0 with B. T. B.

Reaction, before sterilization.....pH 7.0 with B. T. B.

Reaction, after sterilization.....pH 7.0 with B. T. B.

Number of tubes shipped to Gatun.....120 on 4/18/21

Number of tubes shipped to Mt. Hope.....140 on 4/18/21

Chemist's O. K. H. S.

Colonies on trial plates, 0-0-0-0

In conclusion it appears desirable to eliminate the adjustment of the reaction of nutrient agar by titration with P. and to substitute for the latter either B. T. B. or P. R. If the reaction is adjusted qualitatively by means of either of the last two indicators we may expect to have a range in H. I. C. of pH 6.6 to 7.4. Inasmuch as the Committee on the *Standard Methods* of milk analysis recommended a reaction of pH 6.8 to 7.0 and the Committee of the Society of

American Bacteriologists recommended a reaction of true neutrality we suggest that the reaction be adjusted by color standards, prepared either with B. T. B. or P. R. as the indicator, and that the range of H. I. C. be set at pH 6.8 to 7.2, the same as suggested for lactose broth. We also recommend the same range of reaction for nutrient gelatin.

REACTION OF ENDO'S AGAR

Composition, grams; distilled water, 1000; Bacto-agar, 30; Bacto-peptone, 10; Liebig's beef extract, 5.

On page 97 of the *Standard Methods* (1920) under "1. Endo's Medium," the reaction of this medium is specified as follows:

3. Make up lost weight, titrate, and if the reaction is not already between neutral and +1 adjust to neutral.

During 1920 the reaction of batches of Endo's agar at the above step in its preparation varied from +1.5 to 2.2 and from 18 to 23 cc. of N/1 Na_2CO_3 were required per liter to bring the reaction to neutral to P. We did not start to adjust the reaction of this medium to pH 8.0 to 8.2 until the early part of the current year so we have no H-ion concentrations to correspond to the above acidities to P. At the present time we find that the reaction to P., prior to adjustment, averages 1.7 and that 12.5 cc. of N/1 Na_2CO_3 per liter are required to give a pH of 7.2 which is increased to a final pH of 8.0 by the addition of the chemicals. A recently prepared batch of agar gave the following reactions:

First reaction

To phenolphthalein.....	+1.7
To brom thymol blue.....	pH 6.4
12.5 cc. of N/1 Na_2CO_3 per liter added:	

Second reaction

To phenolphthalein.....	+0.5
To brom thymol blue.....	pH 7.2

A portion of this batch was adjusted to a reaction of neutral to P. according to the above quotation and the H. I. C. found to be 8.0 to P. R. which would be increased to a final H. I. C. of 8.8 after the addition of the chemicals. The colonies growing on plates prepared from this batch were unsatisfactory as compared to those developing on the remainder of the original batch which had a final reaction of pH 8.0. Five liters of agar were prepared according to

the formula given at the head of this section and divided into five portions of 1 liter each, to which various amounts of N/1 Na_2CO_3 were added in order to obtain different H-ion concentrations. The five batches were sterilized in the autoclave used for the lactose broth and nutrient agar at 17 lbs. pressure for 20 minutes after this pressure was reached.

To 250 cc. portions of the different batches of this medium, the following amounts of chemicals were added immediately prior to the preparation of the plates:

1.25 grams of Merck's sodium sulphite in 25 cc. of water. 2.5 cc. of a 10 per cent alcoholic solution of basic fuchsin (Harmer Laboratories). In making this solution the fuchsin is allowed to stand in contact with the alcohol for 24 hours at the end of which time it is filtered.

2.5 grams of Bacto-lactose in 30 cc. of water.

TABLE 6

Hydrogen-ion concentrations of five batches of Endo's agar, expressed in pH

BATCH NUMBER	N/1 Na_2CO_3 ADDED	HYDROGEN-ION CONCENTRATIONS, pH		
		Before autoclaving	After autoclaving	Final as poured into plates
	cc.			
1	8.0	7.2	7.2	8.0
2	8.0	7.2	7.2	8.2
3	6.0	7.0	7.0	7.8
4	3.0	6.6	6.6	7.4
5	None	6.4*	6.4*	7.2

Chemicals added to Batch 2 prior to autoclaving.

H-ion concentrations marked * were taken with B. T. B., using standards prepared after Medalia; the others were taken with a set of standards prepared by Hynson, Westcott and Dunning, with P. R. as the indicator.

The sodium sulphite, into which the fuchsin had been poured, was added to the solution of lactose and the resulting mixture poured into the agar. The H-ion concentrations of the five batches at different stages are shown in table 6.

Plates of the five different batches of agar were prepared from tubes of lactose broth inoculated with human faeces and different waters, and compared after 24 hours incubation at 37.5°C . in order to see which batch produced the most distinctive appearing colo-

nies. Three observers judged the colonies on each plate and the summary of their observations is given in table 7.

These tests were repeated several times and we could not detect much difference in the appearance of the colonies growing on batches 1, 2, and 3. In general we thought that better colonies were obtained on batch 1, with those on batch 2 running a close second. The colonies on batch 3 did not carry quite as much metallic sheen and

TABLE 7

Appearance of colonies on Endo's agar after 24 hours incubation at 37.5°C.

BATCH NUMBER	APPEARANCE OF COLONIES ON PLATES INOCULATED WITH A LACTOSE BROTH CULTURE OF HUMAN FAECES
1. pH 8.0	Distinct, typical, with metallic sheen and halo. Agar colored pink. Colonies called very good
2. pH 8.2	Similar to those on batch 1. Agar colored pink. Colonies called very good
3. pH 7.8	Similar to those on batch 1 and 2 but not as good. Agar colored red
4. pH 7.4	Unsatisfactory
5. pH 7.2	Unsatisfactory
BATCH NUMBER	APPEARANCE OF COLONIES ON PLATES INOCULATED WITH LACTOSE BROTH CULTURES OF DIFFERENT WATERS
1. pH 8.0	Distinct, typical, with metallic sheen and faint halo. Agar colored red
2. pH 8.2	Distinct, typical, with metallic sheen. Halo more pronounced than on batch 1 but not strong. Agar colored pink
3. pH 7.8	Distinct, typical, with metallic sheen. Halo of about same distinctness as on batch 2. Agar colored red
4. pH 7.4	Unsatisfactory
5. pH 7.2	Unsatisfactory

had a tendency to be irregular. Batches 4 and 5 were clearly unsatisfactory, as the growth and sheen were always very light. As a result of these tests we decided to adopt a final reaction of pH 8.0 to 8.2.

Dr. Hans Zinsser, College of Physicians and Surgeons, Columbia University, Dr. Leo F. Rettger, Sheffield Scientific School, Yale University, and Dr. Wm. H. Park, Bureau of Laboratories, Department of Health, City of New York, have advised in private communications a final reaction of pH 8.0 to 8.2 for Endo's agar. Fennel and Fisher (1919) and Kliger (1918) also recommend a H. I. C.

of 7.8 to 8.0 as the optimum reaction for Endo's agar. The dehydrated Endo's agar prepared by the Digestive Ferments Company is stated to have a reaction of pH = 7.0. when sterilized for 20 minutes at 15 pounds pressure. In this connection we must call attention to a mistake which we made in our letter of inquiry, sent out in January, 1921, in giving the reaction of Endo's agar as pH 7.0 and not stating that this was the reaction prior to the addition of the sodium sulphite and fuchsin, the former of which increases the H. I. C. to pH 7.8, making this the final reaction of our Endo's agar as prepared at that time. We are of the opinion that the reactions for Endo's agar given in some of the replies to our letter of inquiry were taken before the addition of the chemicals instead of afterwards or as ready for use.

We have used the color standards prepared by Hynson, Westcott and Dunning and some made by ourselves according to Me-

TABLE 8

Hydrogen-ion concentrations of diluted and undiluted Endo's agar, expressed in pH. Indicator, phenol red

BATCH NUMBER	BEFORE ADDITION OF CHEMICALS		AFTER ADDITION OF CHEMICALS	
	2 cc. agar plus 8 cc. water	10 cc. of agar	2 cc. agar plus 8 cc. water	10 cc. of agar
1	7.4	7.7	7.9	8.2
2	7.2	7.5	7.7	8.0

dalia's directions, using P. R. as the indicator in both cases. We prefer to use the latter standards as the colors of the unknown and of the standards match closer. We have observed, however, that we have to use 10 cc. of the undiluted Endo's agar instead of 2 cc. diluted with 8 cc. of distilled water in order to check the pH values obtained by comparison with the standards put up by Hynson, Westcott and Dunning. Table 8 illustrates this point.

We have also noted that the pH value of warm Endo's agar averages 0.2 less than that of the same agar cooled to room temperature so we make it a practice always to cool this agar as well as nutrient agar before taking the H. I. C.

In connection with Endo's agar we have been advised to prepare it according to the Robinson and Rettger (1916) modification, which consists essentially in the use of anhydrous sodium bisulphite in place of sodium sulphite, but we have been unsuccessful in making

up a batch which is practically colorless when cold or even light pink. We believe that our trouble is due to the poor quality of sodium bisulphite because no trouble is experienced in other laboratories in preparing Endo's agar according to this modification. When sodium bisulphite is used instead of sodium sulphite the agar must be adjusted to a different reaction prior to the addition of the chemicals because the former will cause a reduction in the H. I. C. and if a final reaction of pH 8.0 is desired this must be taken into account.

We have observed that Endo's agar stored in a flask in the same refrigerator with lactose broth and nutrient agar for a period of seven days did not change in H. I. C. Ordinarily we make 1 liter of this medium every eight days and pour enough plates to last for three or four days, the latter being stored in the refrigerator also. The agar in plates three days old was found to have the same reaction as when poured, i.e., pH 8.0.

We suggest the abandonment of the adjustment of this medium to a certain reaction to P., either that specified in the *Standard Methods* (1920) or in use in any laboratory and the substitution of a H. I. C. of 8.0 to 8.2 for the final reaction of the agar, i.e., as ready for use in the plates.

EOSINE-METHYLENE BLUE AGAR

Composition; grams: distilled water, 1000; Bacto-agar, 15; Bacto-peptone, 10; K_2HPO_4 , 2.

A batch of this agar was prepared according to the method given by Levine (1918) and divided into two portions. The two portions were sterilized in the autoclave used for the lactose broth and nutrient agar at 17 lbs. pressure for 20 minutes after this pressure was reached. The reaction of one portion was left unadjusted and was found to have a final H. I. C. of pH 7.1 while the final reaction of the other portion was adjusted to pH 8.0 to agree with that of Endo's agar.

To 250 cc. of each portion, the following amounts of chemicals were added immediately prior to the preparation of the plates:

5 cc. of a 2 per cent aqueous solution of yellow eosine.

5 cc. of a 0.5 per cent aqueous solution of methylene blue.

2.5 grams of Bacto-lactose.

Plates of the two portions of agar were prepared from tubes of lactose broth inoculated with human faeces and different waters and compared after 24 hours incubation at at 37.5°C., in order to see

which portion produced the most distinctive appearing colonies. The colonies which developed on the unadjusted agar (pH 7.1) were so much superior to those which developed on the agar adjusted to pH 8.0 that the three observers who judged the colonies had no difficulty in agreeing on the proper H. I. C. of this medium.

The addition of the eosine and methylene blue to this agar makes color so dark that it is difficult to obtain a proper comparison with the standards if the indicator, either B. T. B. or P. R., is added to 10 cc. of the medium. If 2 cc. of the agar, to which the dyes have been added, are diluted with 8 cc. of water and B. T. B. added, the resulting color may be compared without difficulty with standards prepared after Medalia. As the eosine and methylene blue do not alter the H. I. C. of this medium we have decided to take the final reaction on the sterilized agar prior to the addition of these chemicals. If this is done either the color standards put up by Hynson, Westcott and Dunning or those prepared after Medalia may be used as described under nutrient agar.

We have not tried the preparation of this agar with peptones other than Bacto-peptone so we can not be certain that the unadjusted reaction of this medium, prepared with some other peptone, would fall between pH 7.0 to 7.2. Neither have we done any work to ascertain how far below pH 7.0 the reaction could drop without affecting the development of the colonies. As prepared with Bacto-peptone and Baker's analyzed dibasic potassium phosphate we obtain an agar with a final reaction of pH 7.0 to 7.2 on which the various types of colonies of *B. coli* and *B. aerogenes* described by Levine (1921) develop nicely.

Endo's agar and the eosine-methylene blue agar for use in the Mt. Hope and Agua Clara laboratories are prepared in the Miraflores laboratory and shipped to the other two in flasks, 250 cc. per flask. The chemicals necessary for the development of the colonies are added at each laboratory when the plates are poured. When gas develops only occasionally in the fermentation tubes, poured plates of each kind of agar, ready for use, are shipped instead of the flasks.

A permanent record of the composition and reaction of each batch of Endo's agar and eosine-methylene blue agar is kept in a note book similar to that used for nutrient agar and lactose broth.

We suggest a range of pH 7.0 to 7.2 for eosine-methylene blue agar for confirming the presence of members of the *B. coli* group and that the reaction reported be that taken after sterilization, but prior to the addition of the eosine and methylene blue.

REACTION OF PEPTONE MEDIUM FOR THE METHYL RED TEST

This medium is prepared in the Miraflores laboratory according to the formula marked (a) on page 107 of the *Standard Methods* (1920). Proteose-Peptone, Difco, Baker's analyzed dibasic potassium phosphate, and Baker's dextrose are used as the ingredients. As this formula calls for no adjustment of the reaction we have taken the H. I. C. of this medium only recently and found it to average pH 7.4 as ready for use. The substitution of Witte's peptone for Proteose peptone, Difco, gives a medium with an H. I. C. of pH 7.5. We have not accumulated sufficient data on the H. I. C. of this medium to discuss it at greater length.

REACTION OF LITMUS-LACTOSE-AGAR

We abandoned the use of this medium sometime ago but we believe that the final reaction should range between pH 6.8 to 7.2, the same as for nutrient agar and lactose broth. Sørensen gives the pH range of azolitmin as 4.5 to 8.3.

The dehydrated litmus-lactose-agar prepared by the Digestive Ferments Company is stated to be adjusted to a neutral reaction and to have a pH value of 7.0 if sterilized 20 minutes at 15 pounds pressure.

COLOR STANDARDS

1. *Standards prepared by The Hynson, Westcott and Dunning Pharmaceutical Laboratory, Baltimore, Maryland*

Sets of phenol red color standards prepared by this laboratory¹⁴ were used in the Miraflores, Mt. Hope and Agua Clara laboratories until the latter part of 1920 when an article by Medalia (1920) on "'Color Standards' for the colorimetric measurement of H. I. C. pH 1.2 to pH 9.8" was published. The sets contain 15 color standards in sealed glass tubes, 8.2 cm. long and 1 cm. in diameter, which starting with a minimum pH value of 6.6 advance by increments of 0.2 and 0.1 up to a maximum pH value of 8.6, with the value of each standard marked on the glass. The standards are neatly arranged in a long narrow wooden block which slips into a polished case—dimensions, 3.7 by 11 by 28.5 cm.—for protection

¹⁴ Similar sets of color standards in 10 cc. ampoule sets, covering any portion of the range pH 1.0 to 10.0, are advertised by the LaMotte Chemical Products Company, 13 W. Saratoga Street, Baltimore, Maryland, U. S. A.

against light and injury when they are not in use. According to a reprint of an article by Levy, Rowntree and Marriott (1915) sent out with the sets, the standards are prepared according to Sørensen's (1909) directions from 1/15M solutions of acid potassium phosphate and alkaline sodium phosphate which are mixed in the proportions indicated in Table 9 to obtain the desired pH. Five drops of an aqueous 0.01 per cent solution of phenol red are added to the contents of each tube.

An alcoholic solution of P. R. (phenolsulphonephthalein) 0.01 per cent, supplied with the sets, was first used as an indicator but

TABLE 9

Composition of standards in sets furnished by The Hynson, Westcott and Dunning Pharmaceutical Laboratory

pH	ACID POTASSIUM PHOSPHATE	ALKALINE SODIUM PHOSPHATE
	cc.	cc.
6.6	63	37
6.8	51	49
7.0	37	63
7.1	32	68
7.2	27	73
7.3	23	77
7.4	19	81
7.5	15.8	84.2
7.6	13.2	86.8
7.7	11.0	89.0
7.8	8.8	91.2
8.0	5.6	94.4
8.2	3.2	96.8
8.4	2.0	98.0
8.6	Not given	Not given

as it was soon found that the strength of this solution did not remain constant an aqueous solution of the same strength was substituted. The latter solution is kept in an amber glass bottle the rubber stopper of which carries a 1.0 cc. pipette, the upper end of which is protected from dust by a small inverted test tube carrying a wad of cotton. This solution is prepared in liter batches by adding 0.1 gram to about 950 cc. of distilled water in a glass stoppered liter flask. The pH of the distilled water should be taken and if not close to 6.4 the latter should be boiled and cooled before the indicator is dissolved in it. As the indicator dissolves slowly the flask is allowed to stand

one or two days with occasional shakings before the solution is made up to the mark. It is then transferred to a brown bottle without filtering. One liter lasts about 6 months among the three laboratories at the end of which time no change is observed in the indicator on comparison with a new solution.

The comparator block, containing one row of three holes, which was furnished with each set, was found to be unsatisfactory and a

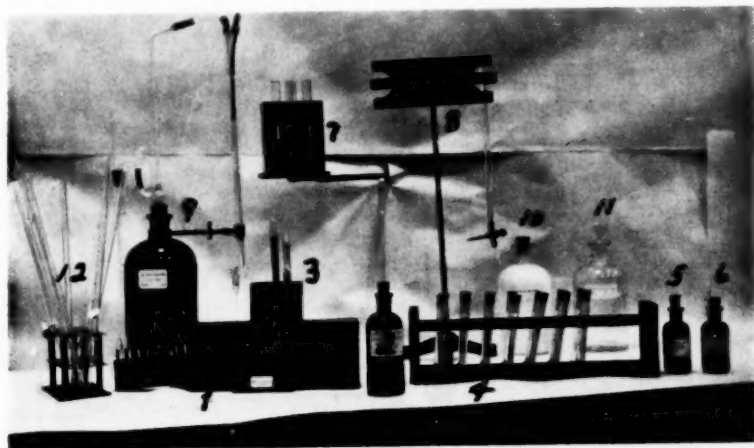


FIG. 2. APPARATUS IN USE IN BACTERIOLOGICAL LABORATORY OF THE MIRAFLORES PURIFICATION PLANT, CANAL ZONE

1. Set of standards; Hynson, Westcott & Dunning Pharmaceutical Laboratory. 2. Phenol red indicator, 0.01 per cent. 3. Comparator block for above set. 4. Brom thymol blue standards prepared after Medalia. 5. Brom thymol blue indicator, 0.02 per cent. 6. Methyl red indicator, 0.02 per cent. 7. Comparator block for Medalia's standards. 8. Burette stand, N/20 NaOH. 9. N/1 NaOH. 10. Stock solution, N/20 NaOH. 11. 0.1 per cent HCl. 12. Pipettes for indicators and media.

new block was made with two parallel rows of three holes each and the necessary slits which was based on one described by Hurwitz, Meyer and Ostenberg (1916). Clark (1917) stated: "The device is optically very imperfect but works fairly well." A piece of ground glass was inserted in the back of the block. The outside of the block as well as the slits should be painted with a black enamel.

The first blocks were made with round holes instead of slits but it was soon found that the latter were superior to the former in mak-

ing color comparisons. There is a difference of opinion about the shape of the holes through which the colors of the unknown and the standards are compared. The blocks provided with the sets were

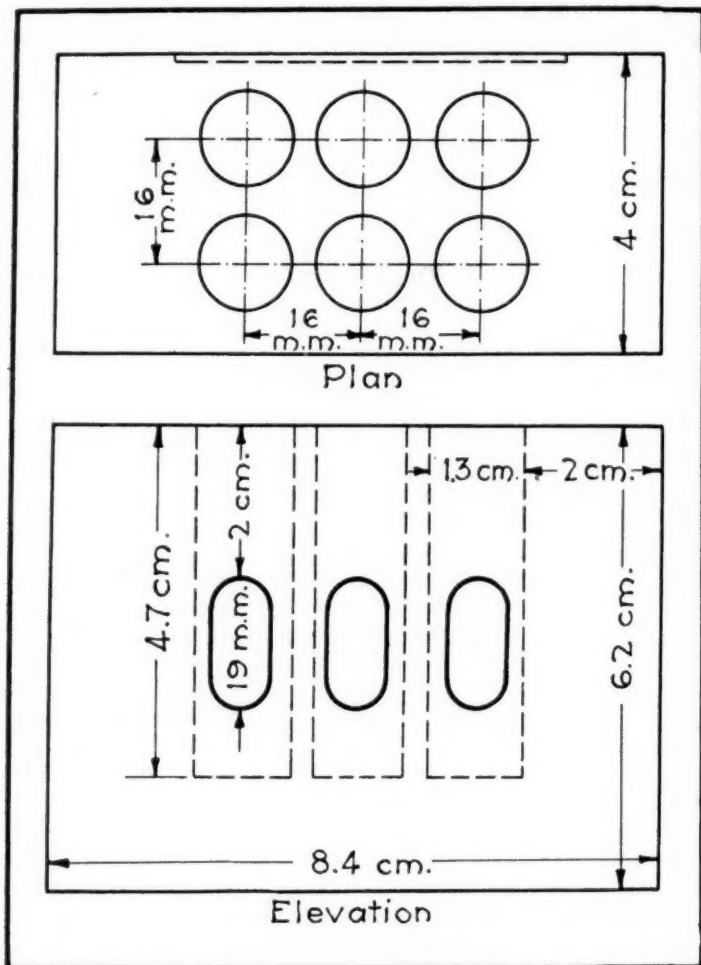


FIG. 3. COMPARATOR FOR USE WITH SET FURNISHED BY HYNSON, WESTCOTT AND DUNNING

made up with slits. Medalia (1920) uses slits in his block. Clark (1920) shows round holes in the block illustrated in figure 7 of his book. Cox and Wood (1920) use round holes of two thirds the

size of those in which the test tubes are set. Six men who have worked in the Miraflores laboratory at different times have preferred to use blocks provided with slits. The details of the block which we use may be found in figure 3.

Two test tubes for holding the unknowns are furnished with each set. It is essential that the test tubes in which the medium is placed be of clear colorless glass and of the same diameter as those in which the standards are sealed. The tubes furnished by the manufacturers at the present time or at least up to November, 1920, were unsatisfactory as their diameter was smaller than that of the tubes containing the standards. As a result of this indifference or carelessness of the manufacturers the buyers of these sets must purchase other test tubes from laboratory supply houses, which not only increases the expense and causes delay but is aggravating. It would be a simple matter for the manufacturers to include six test tubes of the same diameter and of the same glass as those in which the standards are sealed. The cost of the complete (standards, indicator and tubes) set as furnished by the manufacturers was \$8.50 in November, 1920.

The manufacturers state that the glass tubing in which the standards are sealed is not soluble but we have found that flakes of silica appear in the standards at the end of a few months. However they do not appear to interfere with the color comparison. In regard to the stability of the standards the manufacturers state that: "The stability of the colors is believed to be reasonably permanent, but, if there is evidence of fading, the apparatus should be returned for examination and adjustment after six months." Three of the standards in the Miraflores set (25 months old) are cloudy, a private set (6 months old) contains one cloudy standard, while in two other sets (12 months old) all of the standards have remained clear. In all the standards of each set there is a small amount of coarse flocculent material which remains on the bottoms of the tubes if they are not inverted.

The standards of one of the 12 months old sets and of the 25 months old set were compared against those of the 6 months old set through distilled water with the results shown in table 10.

In one case the difference between the standards ran as high as 0.2 but in the other comparisons the difference was always less than 0.1 and might fairly be set at 0.05. Out of 15 standards in each set, 9 of the 12 months old set matched the 9 similar standards of

the 6 months old set. Five of the remaining six standards of the former set were stronger than the similar five of the latter set. Eleven of the standards in the 25 months old set were weaker than the similar standards in the other two sets but in only one case, pH 7.4, did the difference equal pH 0.1. Of the other four standards, two matched the similar standards of the other two sets, one was stronger, while the fourth was broken. These sets will be further discussed under Medalia's standards. Based on our experience with the above four sets we can recommend their use, especially in water

TABLE 10
Comparison of standards of three sets of different ages

pH	AGE SET		
	6 months	12 months	25 months
6.6		Matches	Weaker
6.8		Matches	Weaker
7.0		Matches	Weaker
7.1		Matches	Weaker
7.2		A shade pinker	Weaker
7.3		Stronger	Weaker
7.4	Color faded	Stronger	Nearly 0.1 lower
7.5		Matches	Matches
7.6		Matches	Matches
7.7		Stronger	Weaker
7.8		Stronger	Weaker
8.0		Matches	Stronger
8.2		Matches	Weaker
8.4	Matches 8.2 of 12 months old set.	Stronger	Broken
8.6		Matches	Weaker

works laboratories in which a chemist cannot devote much time to laboratory work, and we consider in general that they may be used for one year, if properly taken care of, before being returned to the manufacturers for adjustment.

In determining the pH value of a medium, lactose broth for instance, by means of a set of these standards, 10 cc. of the broth are placed in each of three test tubes, of the same diameter as that of the standards, and cooled to room temperature, after which 1 cc. of the aqueous solution of P. R. is added to one tube. The broth and indicator are then thoroughly mixed by placing the thumb over the

end of the tube and inverting the latter. The tubes of broth, distilled water and the standards approximating the color of pair no. 2 are then placed in the comparator shown in figure 3 in the positions shown in figure 4. The block is held between the eyes and a well lighted window in such a position that in looking through the slits the color of pair no. 2 may be compared with the colors of pairs nos. 1 and 3. Various standards are tried until the proper one is found to match the color of the broth plus the indicator. At the upper and lower ends of the scale of pH values a color falling between

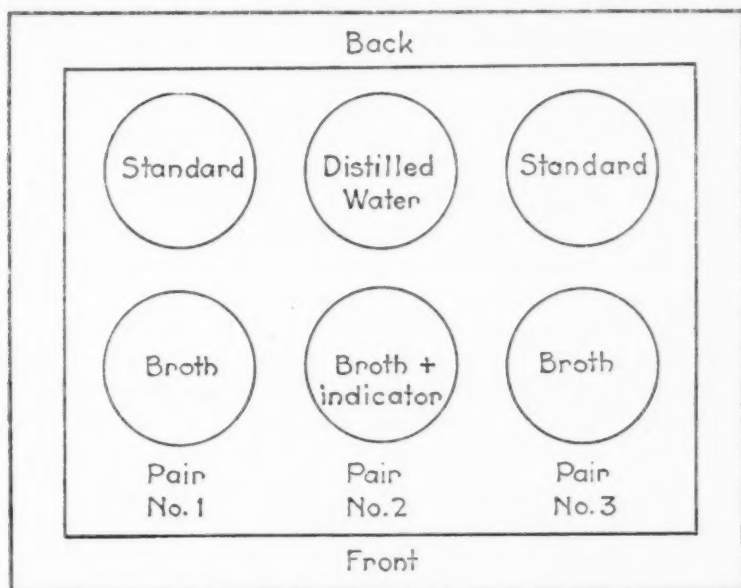


FIG. 4. ARRANGEMENT OF UNKNOWN AND STANDARDS IN COMPARATOR BLOCK FOR DETERMINING H-ION CONCENTRATION

two standards may be read to the nearest 0.05. The quality rather than the quantity of the color of the unknown is to be matched. The tubes of broth, to which none of the indicator has been added, are used with the standards in order to compensate for the color of the broth itself.

To adjust the reaction of a batch of lactose broth to a pH 7.0, the tubes and standards are set up in the manner just described, the standard pH 7.0 being used in pair no. 1 and the standard pH 7.1 being used in pair no. 3. From a burette N/20 NaOH is run

into the tube of broth plus indicator in portions of a few drops at a time, the contents of the tube being mixed after the addition of each portion and the resulting color compared with that of the standards on either side. In this manner there is determined the amount of N/20 NaOH which is necessary to make the color of the broth plus the indicator match the standard marked pH 7.0. Multiply the number of cc. of N/20 NaOH by 5 to obtain the number of cc. of N/1 NaOH to add to 1 liter of broth to adjust the H. I. C. to pH 7.0. In case the medium is too alkaline the titration is made with N/20 HCl in the same manner. Some men prefer to work only with two pairs in the block, omitting either pair no. 1 or no. 3.

After the N/1 NaOH has been added to the batch of broth and thoroughly mixed with it the adjusted reaction is again determined in the same manner. It frequently occurs that the amount of N/1 NaOH theoretically added fails to raise the H. I. C. to pH 7.0 in which case a second addition of the alkali is necessary. The H. I. C. must always be taken after the last addition of the alkali or acid in order to make certain that it is correct before the medium is sterilized.

In the case of lactose broth and nutrient agar, after the amount of N/1 NaOH necessary for the adjustment of the reaction has been determined for one batch, it will be found unnecessary to titrate the succeeding batches with N/20 NaOH as long as the same brands and proportions of the ingredients are used. For example, at the present time we are adding from 40 cc. to 41 cc. of N/1 NaOH to each 4 liter batch of lactose broth to adjust the reaction to pH 7.0 so that it is only rarely that the bacteriologist in charge of the media has to add the alkali in more than two portions, say 40 cc. the first time and 1 cc. the second time, to obtain the proper pH. It frequently happens that the addition of the first large amount will adjust the reaction to the proper pH.

In the first part of his paper Medalia makes the following statement:

The colorimetric method depends on the color changes that take place in certain indicators at different acid strength or H-ion concentration. The H-ion concentration has been determined electrolytically for a number of solutions ("buffer solutions") containing various chemicals in different dilutions. Such solutions when accurately duplicated are supposed to be of the same H-ion content, and should therefore show similar variations in color, in the indicators used. These solutions are referred to as "standard solutions" of known H. I. C.

The difficulties met with in preparing the "standard solutions" of known H. I. C. in the average bacteriological laboratory constitute one reason why

this method has not come into general use, and furnished the principal stimulus for this research.

On account of lack of space we can only give brief notes about the preparation of the indicators and color standards by Medalia; for details those interested are advised to consult the original paper.

The stock alcoholic solution is prepared by dissolving 0.1 gram of the chosen indicator (powder form) in 50 cc. of 95 per cent ethyl alcohol. It should be stored in a sterilized amber colored bottle with a tight fitting rubber stopper in a dark cupboard. The indicators from which color standards may be prepared, together with the ranges of H. I. C. which they cover are given in table 11.

The watery or aqueous indicator solution is prepared by adding 5 cc. of the stock alcoholic solution by a sterile pipette (10 cc. in the case of phenol red) to 45 cc. of distilled water (40 cc. in the case of phenol red) which has been previously sterilized in an amber colored bottle at 10 pounds pressure for 30 minutes. On removal from the autoclave insert a sterilized rubber stopper and store in the dark.

For the color standards Medalia advises the use of B. B. H. test tubes (thick walled, without lips, 130 by 16 mm. outside diameter). Tubes of non-corrosive glass should be used as the alkaline standards corrode the glass of ordinary tubes. It is of great importance to select tubes of the same diameter and of glass which is clear and of the same shades of color.

In tables 3 to 10 inclusive of his article Medalia gives the detailed composition of the pairs of tubes comprising the 'color standards' of thymol blue in the acid range (pH 1.4-2.6), brom phenol blue (pH 3.4-4.6), methyl red (pH 4.6-5.8), brom cresol purple (pH 5.4-6.6), cresol red (pH 7.4-8.6), thymol blue in the alkaline range (pH 8.2-9.4). The tubes are set up as shown in figure 5 and 10 cc. of HCl are added to one row while 10 cc. of NaOH are added to the other row, except in the thymol blue acid range, 0.0001 of HCl is added to the row of tubes marked N/20 NaOH in figure 5 and 0.5 per cent HCl is added to the other row of tubes. The amounts of each indicator to be added to the tubes are the same as shown in figure 5. To save space the tables in detail will not be reproduced here, but table 11 shows the strength of acid and alkali to be used with each indicator, the strength of the latter and the pH of each pair of tubes.

TABLE 11
pH values of pairs of color standards prepared from various indicators

INDICATOR	ACID AND ALKALI	pH OF PAIR NUMBER						
		1	2	3	4	5	6	7
Thymol-blue acid range, 0.02%.....	0.001% HCl 0.5% HCl	1.4	1.6	1.8	2.0	2.2	2.4	2.6
Brom phenol blue, 0.02% ...	N/20 NaOH 0.1% HCl	3.4	3.6	3.8	4.0	4.2	4.4	4.6
Methyl red, 0.02%.....	N/20 NaOH 0.1% HCl	4.6†	4.8	5.0	5.2	5.4	5.6	5.8
Brom cresol purple, 0.02%...	N/20 NaOH 0.1% HCl	5.4	5.6	5.8*	6.0	6.2	6.4	6.6
Brom thymol blue, 0.02%...	N/20 NaOH 0.1% HCl	6.4	6.6	6.8	7.0	7.2	7.4	7.6
Phenol red, 0.04%.....	N/20 NaOH 0.1% HCl	7.0	7.2	7.4	7.6	7.8	8.0	8.2
Cresol red, 0.02%.....	N/20 NaOH 0.1% HCl	7.4	7.6	7.8	8.0	8.2	8.4	8.6
Thymol blue, alkaline range, 0.02%.....	N/20 NaOH 0.001% HCl	8.2	8.4	8.6	8.8	9.0	9.2	9.4

* "According to phthalate and phosphate NaOH mixtures, pairs 3, 4, 5, 6, 7, should read: pH 5.9; 6.1; 6.3; 6.5; 6.7."

† "There was a very slight difference between the phthalate NaOH mixture and the 'standard colors' in the first three pairs: Pair no. 1 = pH 4.7; pair no. 2 = pH 4.9; pair no. 3 = pH 5.1 according to the phthalate NaOH mixture, the rest were the same in both."

The following directions for the titration of culture media are reprinted from Medalia's article.

Titration of culture media

For the titration of a culture medium¹⁵ three test tubes, similar to those used for the "color standards," are filled, each with 2 cc. of the filtered medium

¹⁵ Hot fluid agar or gelatin media, before final titration, can be titrated as described. The 2 cc. of the agar or gelatin when diluted with 8 cc. of water, remain fluid for a much longer time than is necessary to carry out the titration.

Pain No.	1	2	3	4	5	6	7
$N/20$ NaOH-CC. Indicator-CC.							
0.1% HCL-CC. Indicator-CC.							
	Brom Thymol Blue - 0.02% Solution						
PH	6.4	6.6	6.8	7.0	7.2	7.4	7.6
Color	Yellow	Lighten Yellow	Yellowish Green	Green	Bluish Green	Greenish Blue	Blue
	Phenol Red - 0.04% Solution						
PH	7.0	7.2	7.4	7.6	7.8	8.0	8.2
Color	Yellow	Lighten Yellow	Pink Yellow	More Pink Yellow	Beginning Red	Slightly More Red	Red

FIG. 5. COMPOSITION OF "STANDARD COLORS" PREPARED WITH BROM THYMOL BLUE AND WITH PHENOL RED

and 8 cc. of distilled water. To one of these 0.8 cc. of the 0.02 per cent of the brom thymol blue indicator is added and compared with the "color standards" tubes. The other two tubes are used to offset the color of the medium in the "comparator" block described below. The fluid to be titrated is placed in the center row of the "comparator" block having two test tubes of distilled water behind it. On either side are placed the two pairs of test tubes nearest to the pH desired (pairs 4 and 5 pH 7 and pH 7.2). In front of each pair is placed the tube containing 2 cc. of the medium and 8 cc. of distilled water to offset the color of the medium. It is absolutely necessary to compensate for the color of the medium in this way or the result will be misleading. N/20 NaOH is carefully run in the tube that is being titrated until it matches pair No. 4 = pH 7. Twenty-five times the amount of N/20 NaOH used, will represent the amount of normal NaOH necessary to neutralize 1 liter of the medium.

$$\frac{1000 \text{ cc.}}{2 \text{ cc.}} \times \frac{1}{20} = 25$$

If the medium is too alkaline add N/20 HCl until the color matches and calculate the amount of N/1 HCl to be added to one liter of medium in the same way. The same factor is used whatever the pH value selected for the reaction of the medium. The medium should be retitrated after the addition of the alkali or acid as the case may be. The use of the "comparator block" such as described by Hurwitz, Meyer and Östenberg (1916) modified to suit our purpose, was found indispensable.

The block is made by boring three rows of three holes in each row. The holes are 2 cm. in diameter and 9 cm. deep. The block measures 13 cm. high by 9 by 10 cm. Each row of holes is connected by a slit that goes all the way through, 2.5 cm. high by 1.25 cm. wide, the upper edge of the slit being 4 cm. from top of block. The block is painted with black enamel paint including the slits. It is best not to paint the holes that hold the test tubes.

Up to the time of writing this paper, P. R., B. T. B. and M.R. were the only indicators available for our use. We now have all of the eight indicators listed by Clark and Lubs. These indicators may be purchased either from the LaMotte Chemical Products Company, 13 W. Saratoga Street, Baltimore, Md., Hynson, Westcott and Dunning in the same city; or Grahame Chemical Co., Rochester, N. Y. At the present time 10 grams of either brom thymol blue, thymol blue, cresol red, brom cresol purple are worth about \$18.00.

In preparing solutions of B. T. B., P. R. and M. R. both alcoholic and watery, we have followed exactly the directions given by Medalia. We have experienced trouble with both kinds of solutions spoiling and thereby giving erroneous results but the watery solutions have spoiled more frequently than the stock alcoholic solutions. A stock

solution of P. R. kept in a brown bottle in a closet spoiled at the end of 45 days so that a watery solution made from it was altogether too light in color. A stock solution of B. T. B. made up at the same time is still in good condition. During the first few weeks of our work the "indicator watery solutions" spoiled in a few days. The 50 cc. of the watery solution of B. T. B. remain unchanged during the 20 days it lasted. We intend to insert 1 cc. pipettes in the rubber stoppers of the bottles and cover the upper ends by small inverted test tubes carrying a wad of cotton to prevent the entrance of dust. While Medalia does not recommend this procedure we believe that it is preferable to the insertion of a non-sterile pipette into the indicator and it is not very practical to always keep a supply of graduated sterile pipettes on hand. At the present time we are not satisfied with the "indicator watery solutions" and intend to do some work on this feature which seems to be the weakest point in Medalia's methods.

In preparing the color standards we used test tubes, 125 mm. long and 14 mm. inside diameter, without lips and of medium thickness. The tubes were washed only in warm water to avoid the formation of a coating on the glass. We consumed a considerable amount of time in selecting the necessary number of tubes made from glass of the same shade of color but it is essential to do this as otherwise erroneous results will be obtained later on.

In tables 3 and 4 of his paper Medalia gives the composition of each pair of the seven pairs of standards prepared with B. T. B. and P. R., "the color change of each, as nearly as can be described, and the pH value of each pair." We have arranged the data in these tables in diagramatic form in Fig. 5, in which the circles represent the test tubes as set up in a rack and the figures inside show the respective amounts of N/20 NaOH or 0.1 per cent HCl and the watery solution of the indicator to be added to each tube. This diagram will serve as a guide for the preparation of color standards with any of the indicators listed in table 11 of this paper which shows the strengths of the HCl and NaOH used with the different indicators. By following the directions given in the quotation from Medalia's paper under the heading of "Preparation of 'color standards'" in connection with our figure 5 no trouble should be experienced in preparing any of the sets of color standards included in table 11. The N/20 NaOH was prepared from Baker's Analyzed NaOH purified by alcohol without attempting to remove the carbonates,

and its strength was not determined by titration against an acid solution of known value. Sterile distilled water was used however. The 0.1 per cent HCl was prepared from ordinary "C. P." concentrated acid without redistilling it.

The details of the comparator are shown in figure 6. As in the case of the other comparator shown in figure 3 a piece of ground glass was inserted on the back side. No trouble was experienced

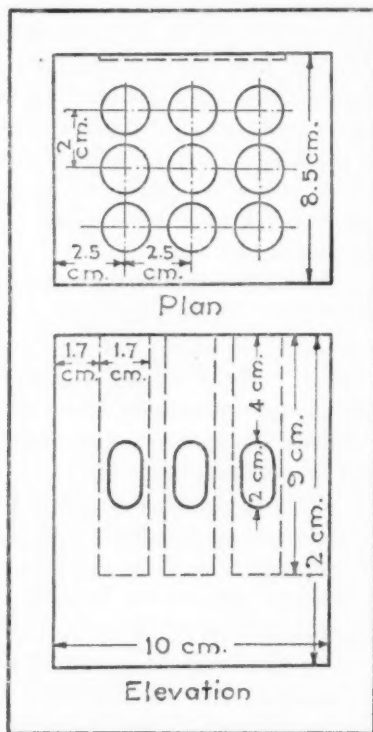


FIG. 6. COMPARATOR FOR USE WITH STANDARDS PREPARED AFTER MEDALIA

in drilling the vertical holes close together on a drill press. In the Miraflores laboratory the comparator was mounted on a swinging bracket fastened to the window frame over the bench so that it is unnecessary for a man to hold it while comparing colors and changing the standards. In determining the H. I. C. of lactose broth or any other medium the tubes of broth and the pairs of color standards are set up as illustrated in figure 7. The color standards must al-

ways be used in pairs of acid and alkali as set up in figure 5, each pair containing a total of 0.8 cc. of indicator. While the pH value of each pair differs by pH 0.2 the readings may be interpolated to pH 0.1. Clark (1920) says:

Certain general considerations have led us to believe that for most work estimation of pH values to the nearest 0.1 division is sufficiently precise, and that this precision can be obtained when the composition of the medium permits if the comparison standards differ by increments of 0.2 pH.

For standardizing the color standards prepared with brom thymol blue and phenol red we used solutions of sodium hydrate and monobasic potassium phosphate prepared according to the directions given on pages 70-76 of Clark's book (1920).

The water used in the crystalization of the salts and in the preparation of the stock solutions and mixtures should be redistilled. So-called "conductivity water," which is distilled first from acid chromate solution and again from barium hydroxid, is recommended, but it is not necessary.

The water which we used was distilled from the still mentioned under lactose broth and immediately before use was reboiled and cooled. The H. I. C. of the water as used was pH 6.8.

Standard buffer solutions are advertised by the LaMotte Chemical Products Company, and by the Grahame Chemical Company 100 Rockingham Street, Rochester, N. Y. Meacham, Hopfield, and Acree (1920) give the following footnote concerning the latter company:

The Grahame Chemical Company now sells a sterile single buffer solution which remains constant indefinitely and covers all pH values from 1 to 14 very accurately and replaces the 5 or 6 buffer solutions employed heretofore. They also furnish sterile buffer tablets, with or without admixed standardized quantities of different indicators, which cover all pH values from 1 to 14 in steps of 0.2 pH. These sterile tablets are added to sterile culture media or to water to give the desired pH values, and have been found very useful in saving time and securing accurate results.

We have not used the products of either of the above companies so we can neither criticise nor recommend their products, but they can undoubtedly give references to reputable parties who have used their products.

In the *Standard Methods for the Bacteriological Examination of Milk*, (1921) the following instructions and comments are given under the heading, "Reaction."

Each batch of finished medium should be tested before use as to its final reaction after sterilization. This test is made as follows: Put 4 cc. of distilled water at 30 to 40°C. (not warmer) in a test tube. Add 1 cc. of the agar to be tested and then 10 drops of the indicator, brom thymol blue 1 (0.04 per cent solution in 95 per cent alcohol). The resulting color should be either a yellowish green or vary to a deeper shade of grass green. To one whose eye is trained this shade of color is sufficient.

These shades may be accurately determined by means of the buffered solutions of Sorensen¹⁶ or of Clark and Lubs.¹⁷

However, they may be approximately determined by comparing the tube of agar containing the indicator with a set of color tubes after the method of Barnett and Chapman.¹⁸

Select 12 test tubes of even caliber and place in two rows of 6 each. In each tube of one row put 5 cc. of a dilute alkali (as, for example, twentieth normal sodium hydroxide). In each tube of the other row put 5 cc. of very dilute acid (one drop of concentrated sulphuric or hydrochloric to 100 cc. of distilled water is sufficient). Avoid stronger acid.

Add indicator to the tubes as follows:

Acid tubes	Alkali tubes	H-ion concentration
9 drops	1 drop	pH 6.2
8 drops	2 drops	pH 6.4
7 drops	3 drops	pH 6.7
6 drops	4 drops	pH 6.9
5 drops	5 drops	pH 7.1
4 drops	6 drops	pH 7.3

The tubes are to be viewed in pairs of acid and alkali, each pair containing the sum of ten drops of indicator.

If preferred, double these quantities may be used throughout and the indicator measured in fractions of a cubic centimeter instead of drops. That is, 2 cc. of agar should be taken for testing. This should be added to 8 cc. of distilled water. 1 cc. of indicator should be used. In comparing with the Barnett and Chapman tubes, use 10 cc. of dilute acid or alkali in each tube, and add the indicator in tenths of a cubic centimeter instead of in drops.

All of the test tubes used in this determination must be of the same diameter and of clear glass.

The pH values corresponding to the color pairs (acid and alkali) prepared by the method of Barnett and Chapman have been worked out by Medalia.

In reference to the first three quoted paragraphs we do not see the sense of making a qualitative determination of the H. I. C. as di-

¹⁶ Sorensen, S. P. L. *Ztschr. Biochem.*, 21, 131, 201, 1909; *Ergebn. Physiol.*, 12, 393, 1912.

¹⁷ Clark, W. M. and Lubs, H. A. The colorimetric determination of hydrogen ion concentration and its application in bacteriology. *Jour. Bact.*, 2, 1-34, 109-136, 191-236, 1917.

¹⁸ Barnett, G. D. and Chapman, H. S. Colorimetric determination of reaction of bacteriologic mediums and other fluids. *Jour. Amer. Med. Ass.*, 70, 1062-1063, 1918.

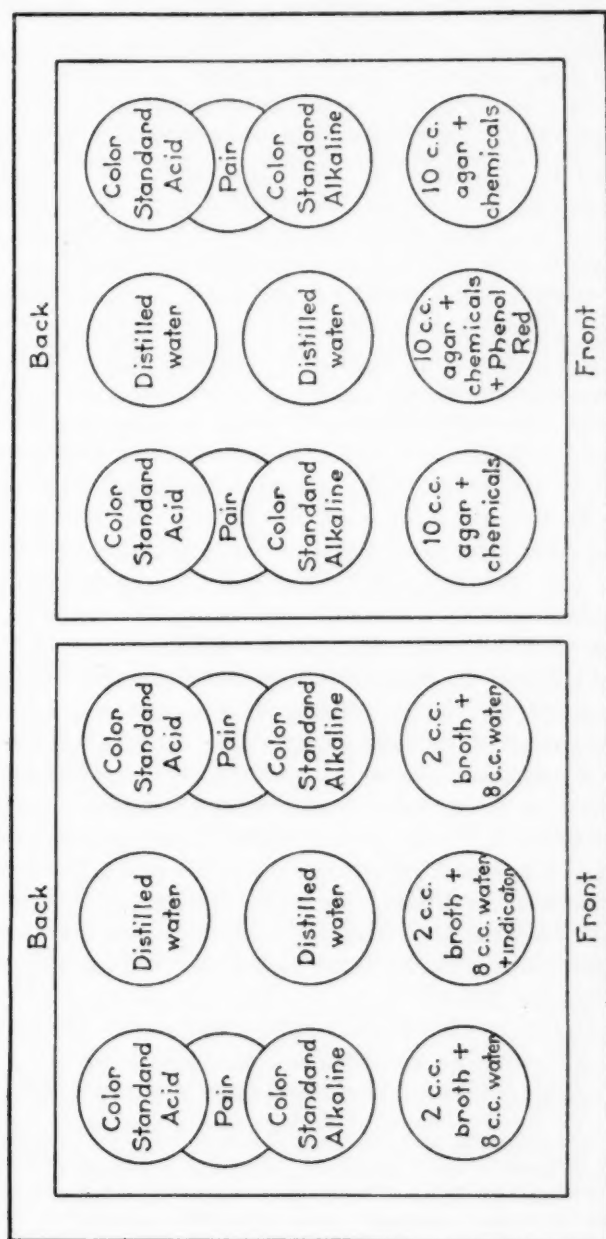


Fig. 8

Fig. 7

FIG. 7. ARRANGEMENT OF BROTH AND STANDARDS IN MEDALLIA'S COMPARATOR

FIG. 8. ARRANGEMENT OF ENDO'S AGAR AND STANDARDS IN MEDALLIA'S COMPARATOR

rected in the first paragraph and checking the shades of color by buffered solutions made according to the directions of Sørensen or of Clark and Lubs. If the time is taken to make the latter solutions, and considerable time is taken in the preparation of the chemicals, why not finish the job and make up a set or sets of color standards according to Medalia to go with these accurately prepared solutions of known H. I. C.? If only a qualitative determination of the H. I. C. of a medium is to be made why not check the shades of color by means of the color chart in Clark's book (1920)?

Inasmuch as the work of Medalia (1920) is referred to in the last quoted sentence and we presume, therefore, although we are not certain that his paper was available at the time these *Standard Methods* were prepared, we are of the opinion that the space given to the preparation of color tubes after Barnett and Chapman should have been given preferably to a brief description of the preparation of Medalia's color standards. Perhaps more space would have been required for the description but a slight increase in the cost (\$0.30) of these *Standard Methods* would not have put them out of anybody's reach and as far as accuracy is concerned there is no comparison between the color standards of Medalia and of Barnett and Chapman because those of the former are easily superior. In addition to their being more accurate, there is nothing difficult in their preparation and they are sufficiently permanent to compensate for the increased time required for their preparation. In view of the increasing use of color standards for determining the H. I. C. of media we think that more space should have been given to this subject in the *Standard Methods for the Bacteriological Examination of Milk*, because it is of importance to men in both water and milk laboratories and on account of being published later than the *Standard Methods of Water of Water Analysis* (1920) the opportunity was presented for a more complete description of the subject than was possible in the latter book.

According to Cox and Wood (1921) sets of phenol red color standards have been in use in the laboratories of the Army Medical School and have been sent out to the other larger Army laboratories for use:

The use of these indicators and standard buffer mixtures in the adjustment of the reaction of bacteriological media was begun in the summer of 1918 at this institution,¹⁹ and has been continued with increasing satisfaction and

¹⁹ Division of Laboratories, Army Medical School, Washington, D. C.

confidence. The question of more or less permanent standards arose, and was met first by the use of standard solutions, with indicator added, in test tubes closed with corks wrapped in tin foil. These solutions were found to hold their colors very well for a number of weeks, when carefully protected from the light when not in actual use, and kept tightly corked. The sealing of these solutions in ampoules was next tried, and found to be very satisfactory, if the ampoules were of the best quality glass. Phenol red sets were sent out to the larger Army laboratories at three or four months intervals, and the use of this method of adjustment of the reaction of media was urged. On renewal, the return of the old sets was requested, and their colors compared with those of fresh standards. At first, these comparisons showed marked changes in the old sets, the tubes above 7.6 as a rule showing the intensest possible color with phenol red, showing a reaction at least as alkaline as 8.4. (The phenol red range is extensive enough for media adjustment for routine work with the ordinary pathogenic bacteria.) As the quality of the glass of the old sets improved, the changes became less marked, and at present the standard sets distributed from the Army Medical School are test tubes of Pyrex or Non-sol glass, drawn out in the upper third before the addition of the solutions, and then sealed in a blast. We hope that these standards will prove to hold their colors very truly for at least five or six months.

We have made a considerable number of comparisons of the H. I. C. of lactose broth, nutrient agar, and Endo's agar with the color standards of the sets obtained from The Hynson, Westcott and Dunning Pharmaceutical Laboratory and those which we have prepared according to Medalia's directions. In Tables 12 and 13 there will be found the results of some of the comparisons.

From the above table we see that four observers, working independently with three Hynson, Westcott and Dunning sets of different ages, obtained H-ion concentrations on the same batch of nutrient agar which differed only by pH 0.1, the minimum reading being pH 7.1 and the maximum pH 7.2. The 6 months and the 12 months old sets gave the same readings. The same observers, using the same nutrient agar and Medalia's color standards prepared with B. T. B. differed only by pH 0.1, the minimum reading being pH 6.9 and the maximum, pH 7.0, using another set of Medalia's color standards prepared with P. R., the same difference and the same maximum and minimum were obtained. Comparing the readings taken with either set of Medalia's standards with these taken with the 6 months old set of Hynson, Westcott and Dunning, there is found a maximum difference of pH 0.3 and a minimum difference of pH 0.1. For any one observer using the standards of either Hynson, Westcott and Dunning (6 months old) or of

Medalia the maximum difference in the H. I. C. of the agar was pH 0.2. Each of the four observers obtained a lower H. I. C. of the nutrient agar with Medalia's B. T. B. color standards than with the 6 months old Hynson, Westcott and Dunning set of color standards.

TABLE 12

Hydrogen-ion concentrations of nutrient agar after sterilization, expressed in pH

OBSERVER	STANDARDS FROM HYNSON, WESTCOTT AND DUNNING			MEDALIA'S STANDARDS	
	6 months old	12 months old	25 months old	Brom thymol blue	Phenol red
A	7.1	7.1	7.2	6.9	6.9
B	7.1	7.1	7.2	6.9	6.9
C	7.1	7.1	7.1	7.0	7.0
D	7.2	7.2	7.2	7.0	6.9

TABLE 13

Hydrogen-ion concentrations of two batches of lactose broth after adjustment of reactions, expressed in pH

OBSERVER	STANDARDS FROM HYNSON, WESTCOTT AND DUNNING			MEDALIA'S STANDARDS	
	6 months old	12 months old	25 months old	Brom thymol blue	Phenol red
First batch					
A	7.3	7.3	7.4	7.0	7.0
B	7.3	7.3	7.4	7.0	7.0
C	7.3	7.2	7.4	7.0	7.0
D	7.3	7.3	7.3	7.0	7.0
Second batch					
A	8.6*	8.6*	8.6*		8.1
B	8.6*	8.6*	8.6*		8.2
C	8.6*	8.6*	8.6*		8.2
D	8.6*	8.6*	8.6*		8.1

* The hydrogen-ion concentration of the broth was greater than 8.6 but this was the highest standard in the sets.

From the above table we see that four observers, working independently with the same three sets of Hynson, Westcott and Dunning standards, obtained H-ion concentrations on the "first batch" of lactose broth which differed only by pH 0.2, the minimum reading

being pH 7.2 and the maximum, pH 7.4. The 6 months and the 12 months old sets gave the same readings with one exception. The same observers, using the same lactose broth and Medalia's color standards, prepared with B. T. B., agreed on the readings, pH 7.0 being obtained by each of the four. The same was the case with the P. R. color standards. Comparing the readings taken with either set of Medalia's standards with those taken with the 6 months old set of Hynson, Westcott and Dunning there is found a maximum difference of pH 0.4 and a minimum difference of pH 0.2. In all cases a lower H. I. C. was obtained with Medalia's color standards than with the 6 months old set of Hynson, Westcott and Dunning.

The "second batch" of lactose broth in the same table had been adjusted to a neutral reaction with phenolphthalein. The four observers found that the color produced with phenol red was greater than that of the highest standard in the Hynson, Westcott and Dunning sets, pH 8.6. Using Medalia's P. R. standards two of the observers obtained a H. I. C. of pH 8.1 while the other two obtained pH 8.2. In the case of this broth the H. I. C. obtained with the Hynson, Westcott and Dunning sets was clearly way off because the shades of color of the broth plus the P. R. and of the standards were entirely different, so much so that no attempt would be made to use these sets except to show that Medalia's standards were greatly superior.

In all comparisons we have found that the shades of color of 2 cc. of the medium plus 8.0 cc. of water plus the indicator and of Medalia's standards (prepared either with B. T. B. or P. R.) matched more closely than did the shades of color of 10 cc. of the medium plus 1 cc. of P. R. and of the Hynson, Westcott and Dunning standard. The superiority of the first method of determining the H. I. C. is due partly to the greater brilliancy of the standards and indicator, partly to the effects of the dilution, partly to the use of tubes of larger diameter, and partly to the use of the triple sets of tubes in the comparator. Between the B. T. B. and P. R. standards we prefer to use the former when the range of H. I. C. permits because we find the color shades match a little closer. In determining the final reaction of Endo's agar, to which sodium sulphite and fuchsin have been added, we find that the shades of color, developed on the addition of P. R., match very closely. We use the set up shown in figure 8 in this case.

Within the range of pH 6.8 to 7.2, in which the reactions recommended in this paper for lactose broth and nutrient agar will fall, it is our opinion, based on the data in tables 12 and 13 that the H. I. C. of either kind of media may be determined within, a maximum variation of pH 0.3 from the true value. For Endo's agar the final reaction may be taken before the addition of the fuchsin and sodium sulphite at which point the H. I. C. will be about pH 7.0 or 7.2. However at the present time or until such of Medalia's standards are placed on the market we recommend the use of the Hynson, Westcott and Dunning sets of standards or similar sets from other companies in the smaller laboratories because the final reactions of media may be obtained more accurately than by the qualitative method, as we term it, in which the reactions are adjusted by watching for a change in color of the indicator without any comparison with standards.

Whenever it is possible we recommend the use of the color standards prepared according to Medalia's directions because the shades of color of the unknown and the standards match closer and the H. I. C. may be determined more accurately or within a maximum variation of pH 0.1 from the true value, providing of course that the standards have been carefully prepared and checked against solutions of known H. I. C. For routine work, including the preparation of nutrient broth, sugar broths, nutrient agar and gelatine, lactose agar, and Endo's agar and the adjustment of the final reactions within the ranges recommended in this paper, one may get along very nicely with a set of B. T. B. standards with a range of pH 6.4 to 7.6 if the final reaction of Endo's agar is taken at the point mentioned in the preceding paragraph.

SUMMARY AND CONCLUSIONS

We are of the opinion that the reactions of culture media used in water works laboratories should be adjusted by the colorimetric method of determining the H-ion concentration.

We are of the opinion that definite H-ion concentrations should be used for the reactions of nutrient agar, nutrient gelatine, sugar broths, etc., rather than changes in indicators described as "faint pink with phenol red," "distinct grass green" with brom thymol blue, or "the first faint trace of permanent pink to appear with phenol red."

For nutrient agar and gelatine, lactose agar, and nutrient and sugar broths, we suggest that the final reactions, i.e., the reactions of the media as ready for use, be adjusted to come within the range of pH 6.8 to 7.2. For Endo's agar we suggest that the final reaction, after the addition of the fuchsin, sodium sulphite or sodium bisulphite, and lactose, be adjusted to fall within a range of pH 8.0 to 8.2.

In reporting the reaction of a medium, the H. I. C. given should be the final one, i.e., the reaction of the medium as ready for use, unless otherwise stated.

To men in smaller laboratories, with a limited amount of time, we recommend a set of color standards prepared by one of the commercial laboratories.

For more accurate work we recommend the use of color standards prepared according to Medalia's (1920) directions, for we have found them to be superior to those of Barnett and Chapman and those offered for sale by commercial laboratories.

We wish to acknowledge the assistance of Mr. A. H. Khachadoorian who prepared the $\text{KH}_2\text{PO}_4\text{-NaOH}$ mixtures of known H. I. C. and checked various readings with the color standards. Messrs. A. M. Nolte, W. C. Dunn, and W. H. Beers, Jr., have also assisted us as observers. We also wish to thank the directors of various laboratories who kindly answered our letter of inquiry regarding the reactions of culture media.

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GENERAL REQUIREMENTS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS IN REGARD TO WATER WORKS¹

BY ROBT. E. ANDREWS²

The Baltimore conflagration of 1904 was the immediate cause of the entry of the National Board of Fire Underwriters into municipal affairs on a large scale. During the fourteen years previous to that date, a large number of reports on cities had been prepared by single inspectors, usually fire chiefs of long experience, and, as was natural from their training, little space was devoted to water works. The Baltimore fire caused a direct property loss of \$50,000,000 and aroused the insurance companies to the possibility of similar fires in other cities.

This conflagration was carefully studied from many angles and the preparation of reports on all the large cities of the United States was begun in a systematic way. Instead of single inspectors the work was carried on by parties composed of engineers specially trained in the branch of the work they were to handle. In addition to description and criticism of water systems, the reports outlined fire departments, fire alarm systems, actual structural conditions and laws and ordinances relating to building and to fire hazards—all leading up to a discussion of the possibility and probability of a conflagration—and followed by recommendations for improving conditions thought to be unsatisfactory.

The engineers preparing these reports were pioneers in a new line. There were no fixed standards by which a water system, or the other features considered, could be judged from the fire protection point of view. What standards there were in regard to these matters, were the results of opinion rather than of experience. That the reports did not go far wrong is shown by the one issued on San Francisco in October, 1905, in which the catastrophe of the following

¹ Presented at the second annual meeting of the California Section, October 1, 1921.

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April is vividly foretold. This conflagration, with a property loss very greatly exceeding that of Baltimore, again emphasized the importance of the work, and brought home to the insurance companies the immense aggregation of values which can be destroyed by a single fire. Except for the period of the war the issuing of reports on the larger cities of the country has gone on without interruption. Usually about thirty-five reports are published each year. Copies of the printed report are sent to city officials, civic organizations such as Chambers of Commerce, Rotary and Kiwanis Clubs, to newspapers and to influential citizens particularly interested in fire protection.

By 1916 approximately 300 cities had been reported on, some of them three times. The amount of information acquired in the prosecution of this work was enormous. Enough data were on hand so that careful studies could be made of the various features upon which effective fire protection depended. Conditions in one city were compared with those in others of the same class. Conclusions were no longer based on opinion but on the results of many years of experience. If, for example, we asked that a distribution system be composed of mains of certain sizes, it was because thousands of tests had told us that suitable quantities of water for fire protection could not be obtained unless the mains were of the sizes recommended.

In fact, we had so much information in our files and had acquired so much experience in this particular field, that we felt justified in taking an ambitious step forward—namely, grading cities with reference to their fire defences and physical conditions. Up to this time, the work of the National Board of Fire Underwriters had been confined almost entirely to the larger cities. It was felt, however, that any system of grading which might be adopted, should apply equally well to cities and towns of all sizes. Accordingly, an intensive study was made of a large number of small towns and villages, and the standards modified, where necessary, so that all would be considered with equal fairness.

The plan adopted is like that of marking a school-boy's examination paper, where so much is taken off for every mistake. The sum of the maximum points of deficiency totals 5,000 and is divided in accordance with the relative values of the features as follows:

	<i>points</i>
Water supply.....	1700
Fire department.....	1500
Fire alarm.....	550
Police.....	50
Building laws.....	200
Hazards.....	300
Structural conditions.....	700
Total.....	5000

That is, a city where the fire defences and physical conditions are excellent would have few points of deficiency, and one where conditions are as bad as possible would approach 5000 points. The water supply is given a weight of about one-third of the total requirements. It is considered as being of slightly more importance than the fire department, as a water system is of some value for fire protection where there is no organized fire department, but a fire department without water is almost helpless. A good water supply in connection with a poor fire department, or vice versa, is obviously of less value than if both are good. In recognition of this fact an equalizing charge is made where the two features differ greatly in efficiency.

The *Grading Schedule* has been received with marked enthusiasm. A number of engineering societies, some of them national in scope, have investigated the schedule and given formal approval. Insurance rating organizations use it for classifying cities and towns in all states of the Union except in Texas, New Jersey, part of Pennsylvania and on the Pacific Coast. Its use for this purpose precludes any possibility of discrimination and allows every town to know in what respect and to what extent its fire defences are deficient. As a guide for outlining improvements for fire protection it is invaluable.

A water works is judged from two view-points, *adequacy* and *reliability*. To be considered adequate, a system must be capable of supplying a reasonable quantity for fire protection for a period of ten hours, in addition to domestic consumption at the maximum daily rate. It is frequently suggested that we ought to base our calculations on the maximum hourly rate instead of the maximum daily rate. We feel, however, that it would be going to the extreme to assume that a serious fire would occur exactly at the peak hour of the highest day. Fires of the magnitude with which we are chiefly concerned ordinarily burn for a longer period than the dura-

tion of the peak hour. There is always the possibility that citizens may suspend lawn sprinkling during a large fire and that water works' officials may operate gate valves so as to reduce the flow to parts of the city remote from the fire; both of which would reduce the domestic consumption. Furthermore, pressures are naturally reduced in the vicinity of a large fire, and sometimes the area affected is of sufficient size to cause a noticeable decrease in consumption. For these reasons we think it preferable to use the maximum daily rate.

The quantity asked for fire protection in the central business district, is usually that determined by a formula based on population, which was worked out by Metcalf, Kuichling and Hawley and presented in a paper read before this Association at its annual meeting in 1911.³ The quantities required are shown in the following table.

POPULATION	REQUIRED FIRE FLOW, GALLONS PER MINUTE FOR AVERAGE CITY	POPULATION	REQUIRED FIRE FLOW, GALLONS PER MINUTE FOR AVERAGE CITY
1,000	1,000	28,000	5,000
2,000	1,500	40,000	6,000
4,000	2,000	60,000	7,000
6,000	2,500	80,000	8,000
10,000	3,000	100,000	9,000
13,000	3,500	125,000	10,000
17,000	4,000	150,000	11,000
22,000	4,500	200,000	12,000

When the population exceeds 200,000 provision should be made for two fires occurring at the same time, and we ask for 12,000 gallons a minute for the larger fire and from 2,000 to 8,000 gallons for the second fire. The total quantity in all cases includes an allowance for loss from broken connections and hydrants left open, incidental to a large fire.

Occasionally the quantity indicated by the formula is modified as required by unusual local conditions. For example, in the vicinity of large cities there are generally suburban communities having good sized populations but with mercantile districts of very small area and without congested construction in comparison to the population. Obviously to require the average fire flow in this case would be unfair. Conversely, there are cities of small population,

³ JOURNAL, Proceedings, 1911, p. 55.

remote from other cities, which are surrounded by thickly settled rural territories and which are in fact the mercantile center of a population several times that within the municipal limits. Such cities require more than the average fire flow.

The time limit of ten hours required for the fire flow has been determined upon as closely approximating actual needs. Nearly all conflagrations have lasted much longer than this—some of them ten times as long. The use of water, however, begins gradually and increases for several hours as more lines of hose are brought into play. The peak load ordinarily continues several hours and as the fire is brought under control the quantity gradually becomes less. Ten hours of full fire flow probably amounts to the average quantity of actual flow at the variable rate. For towns under 2,500 population the time limit has been reduced to five hours.

In speaking of the fire flow required, I characterized it as being *reasonable*. It is merely the quantity which good practice demands should be available and not that which might be needed under the most extreme conditions. In the Baltimore conflagration water was actually used at the rate of 33,000 gallons a minute, yet in our reports we have asked only that 12,000 gallons a minute should be available about any block in the congested business section, with 6,000 gallons a minute additional for a second fire occurring at the same time. A few months after our report on Hartford, Connecticut, was issued, in 1916, a fire occurred at which water was used at exactly the rate we requested. This fire did not spread outside the building in which it originated, and was very much smaller, so far as water needs are concerned, than other fires which are probable. For four hours during the Atlanta conflagration in 1917 water used on the fire was at the rate of 13,000 gallons a minute, yet the fire occurred in a residential section for which we modestly asked 2,500 gallons a minute about any block. Examples like these could be multiplied indefinitely. If there is any error in the quantities we recommend, I believe it is in not asking enough.

The second viewpoint by which a water system is judged is *reliability*. In general, reliable fire protection requires duplication of such parts of a water system as may reasonably be expected to become inoperative. Aqueducts of good design and of substantial construction, such as masonry or concreted steel, are considered sufficiently dependable as not to require duplication. A paper on the reliability of pumping stations was read by Clarence Goldsmith,

an engineer of the National Board of Fire Underwriters, at the 1917 convention of this Association and covers this phase of the subject excellently.⁴

It is recognized that a so-called gravity system—one delivering supply direct to the city from the source without the use of pumps, is preferable from a fire protection standpoint, but a well-designed and properly safeguarded direct pressure system, such as the high pressure fire systems of some of our large cities, so nearly approaches the gravity system in adequacy and reliability that no distinction is made between the two types.

The introduction of storage, either elevated and supplying the distribution system or for suction supply, off-sets to a greater or less degree the need of duplication in various parts of a system, the value of the storage depending upon its amount and location. In general, all storage lessens the requirements of those parts of the system through which the supply has already passed. It is assumed that storage adequate to meet maximum consumption demands for five days plus fire flow for ten hours, is sufficient to permit the making of most of the repairs, alterations or additions incident to the operation of a water supply system. Where storage fluctuates materially during the twenty-four hours, the minimum storage maintained is used in all calculations. In no case is a rate greater than the actual capacity of the mains from the reservoir considered. Owing to the decrease in pressure when water is drawn down in standpipes, only the capacity of the top twenty-five feet is considered as effective storage, unless the standpipe is on elevated ground and fire engines are generally used.

In grading a water system deficiency charges are made under thirty-two separate headings. To describe these in detail would require more time than is available. Briefly stated, however, the principal requirements are as follows:

The chief executive, either superintendent or chief engineer, shall be competent and qualified by experience. Employees shall not be subject to removal by every incoming political administration. Records and plans shall be such as to facilitate repairs and to permit the efficient operation of the system. Emergency crews shall be quickly available. Fire alarms, particularly in direct pressure systems, shall sound in appropriate water works quarters.

⁴ JOURNAL, December, 1917, p. 432.

Two items are of fundamental importance and may have very heavy charges. The first is based on the normal ability of the source of supply, including impounding reservoirs, and all parts of the supply works, to deliver the required quantity to the district being considered. The second is the reliability of the source of supply. Under supply works we include intakes, suction lines, pumps, boilers, stacks, air compressors, filters and force or supply mains. The extent of deficiency of each part of the supply works is considered and the percentage of deficiency of the most serious is used for computing the charge. Under reliability we consider such items as frequency and duration of droughts, physical condition of intakes, danger from earthquakes, floods, forest and grass fires, ice dams and other ice formations, and silting up or shifting of channels.

Pumping capacity must be such as to allow two pumps in reserve. The deficiency charge, however, is very small for the second reserve unit and is still further reduced for small cities. In cases where both low-lift and high-lift pumps are provided and reliability of supply is dependent on both, they are considered separately, and, if necessary, charges are made for each. Boiler capacity with a reserve of one-fourth the entire capacity, and in any case at least one boiler, must be sufficient to operate the pumps and auxiliaries required. Electric transmission lines, steam piping, or gas or oil piping to internal combustion engines or boilers, shall be so arranged that a failure in any line, or the renewal of a valve, transformer or oil pump, would not prevent maintaining, in connection with storage, maximum domestic consumption for two days and fire flow for ten hours. Pumping stations and other portions of the plant shall contain no combustible material in their construction, shall be protected from exposures and have suitable private fire protection. When pumps are electrically operated the generating station supplying them should have the same features of reliability that are required in the pumping station.

Although aqueducts of substantial construction are not required to be duplicated, suction or gravity lines to pumping stations, flow lines from reservoirs, force mains, etc. shall be of such capacity and so laid out that no single break will prevent the delivery of the required quantity. Such lines shall be laid as not to endanger each other, and their failure at stream crossings, railroad crossings and other points where physical conditions are unsatisfactory shall be guarded against. In connection with supply mains, there must be

arteries and secondary feeders of sufficient size extending throughout the distribution system. The gridiron shall be made up of minor distributors, 6 inches or larger in diameter, connected at intervals not exceeding 600 feet and free from dead ends. These charges, however, are reduced where pressures are high. In other words, it is a certain quantity of water that is wanted, rather than a strict adherence to a rule. Pipe in unreliable condition, whether cement-lined, wood or metal, is charged for.

The distribution system shall be equipped with a sufficient number of gate valves so located that no single case of accident, breakage or repair to the pipe system will necessitate the shutting from service a length of pipe greater than 500 feet in high value districts, or greater than 800 feet in other sections.

The requirements for hydrant spacing are based on the assumption that hose lines shall not exceed 500 feet in length when laid directly from hydrants, and 600 feet in length when supplied by fire engines. The unit of measurement which has been adopted for determining hydrant spacing is the area served by each. The area required depends on the quantity of water which the fire department may be called upon to handle. In the largest cities the average area served by a hydrant in the congested district shall not exceed 40,000 square feet, but in villages where a fire flow of only 1,000 gallons a minute is asked for, an average area of 120,000 square feet is permissible. Hydrants shall be maintained in good operative condition, shall be of such size and type as to deliver 600 gallons a minute with a friction loss of not over $2\frac{1}{2}$ pounds, and connections to mains shall be gated.

I imagine some of you will say it is well to aim high. I admit that our standards are high, but they are by no means unattainable. The very fact that so many water systems approach complete compliance shows that our requirements are not excessive. Of sixteen cities on the Pacific Coast, on which the National Board of Fire Underwriters have recently issued reports, three have water works which may be considered as 90 per cent perfect from the standpoint of fire protection. One grades as high as 95 per cent. And in this state, where so many of the water systems are designed for abnormally high consumption and are capable of meeting the maximum hourly rate, the margin available for fire-fighting is unusually large. As compared with other sections of the country the typical California system is decidedly superior.

DISCUSSIONS

THE REACTIONS OF CULTURE MEDIA¹

It is to be hoped that the paper by Messrs. Bunker and Schuber will have a wide circulation among laboratory workers who are seeking to place their work on the higher level established by developments in recent years along the line of hydrogen ion concentration. The paper merits careful study in that it shows the application of this new knowledge and points out numerous precautions and pitfalls.

Considerable space has been devoted to a criticism of the subject matter in certain chapters of the *Standard Methods of Water Analysis* of the American Public Health Association, and also to omissions of certain kinds of information in this volume.

The reason for many of the shortcomings of the present edition of *Standard Methods* is found in the admission of the authors of the paper that it was compiled in advance of much that is known today and that it is not intended as a text book. The lack of such a book has been keenly appreciated for a long time by teachers, students, and laboratory workers, but it has never been the object of the Committee of the American Public Health Association to supply this need. Such has been the policy ever since the inception of *Standard Methods*, the editing of which has always been a labor of love and hardly calling for elaborate compilation. We must rely upon our teachers and such books and monographs as appear from time to time to supply the details necessary for the successful conduct of official methods.

The aim of *Standard Methods* has been to set down procedures which are accepted as the best after thorough trial. Consequently, there is a lag between important advancement and its adoption as an official procedure. The delay permits of a general dissemination of and familiarity with any newly incorporated procedure, the details of which are already available in print. Recent editions of *Standard Methods* are open to criticism for departing in some sections from this original aim. Procedures have been adopted one

¹ This JOURNAL, p. 63.

year to be cast aside the next, and the rapid change has weakened the prestige of an official publication. Attempted progress has been too rapid, suggestions have been adopted from round-table discussions without allowing sufficient time for general trial in the laboratory. There has been too little research and too much discussion.

It is pleasing, therefore, in the face of such conditions to have available for study and later corroboration a paper of the magnitude of the one presented by Messrs. Bunker and Schuber. The determination of H-ion concentration is a procedure which will subsequently find wide application in water works laboratories. The trend is that way and we shall profit sooner by it if there are made available more studies of the scope and character of the ones presented by these authors. Their paper goes a long way toward supplying the supplementary information on the subject, the lack of which they decried in Standard Methods. It is long, but gives a great deal of material which will serve to enlighten the reader who may be none too familiar with the subject. Full details of their own work are also included. In my opinion it would have been better to have brought forward to the opening pages of the paper the description of the preparation and use of color standards made up after Medalia's procedure. These register a real advance in laboratory methods and could well be emphasized at the expense of some of the criticism of the existing Standard Methods.

The experiments which compare the relative accuracy of phenolphthalein and the more sensitive indicators in registering H-ion concentration are of great value in the final adoption of the latter for the purpose. Likewise, the changes in the H-ion concentration of media during autoclaving, storage and dilution have been dealt with in a manner to give needed information on the subject. Studies of this kind will do much to furnish accurate knowledge in a relatively new field and assure the elimination of optional and questionable procedures from future editions of our Standard Methods. They will be hailed by committees having the publication in charge and by workers to whom the subject is new and who are still timid about making changes in established practices.

MELVILLE C. WHIPPLE.²

² Instructor in Sanitary Chemistry, Harvard Engineering School, Cambridge, Mass.

"Why not make the 'Standard Methods' a little more human, a little more interesting, a little more *helpful*?" In propounding this suggestive question the authors unquestionably have spoken for a goodly majority of all who either make use of the "Standard Methods" or who would make use of such were they more helpful. The writer has in mind as this majority the following:

1. Graduates in chemistry, chemical engineering or bacteriology who may not have had courses in the chemistry and bacteriology or water and sewage.

2. Experienced engineers who have never had the opportunity of obtaining a knowledge of the chemistry and bacteriology of water and sewage or who have not had the time or opportunity to keep in touch with the subjects. Such men are daily becoming more aware of the necessity of an understanding of chemical, physical and bacterial phenomena. To these men a book of "Standard Methods," containing helpful notes and explanations where advantageous, would find its place on the desk as a reference book of real value.

3. Small plant operators.—In this class fall the many operators of small filter-plants or sewage-disposal plants. Although without more than a high school education, these men are anxious in many cases to understand and make the necessary laboratory tests. Constantly requests are coming in from them for help along this line. Here an improved "Standard Methods" would serve a thoroughly useful purpose.

The authors have also made reference to the fact that it is almost impossible for individuals who are interested in new developments in the laboratory to keep thoroughly posted on the subjects because of the large number of different publications which print the matter, few of which are available to men in small places unless they have sufficient funds to subscribe to all of them. The writer falls in this class and appreciates therefore the desirability of having incorporated in the book of "Standard Methods" greater details on the newer laboratory procedures.

It is believed that Messrs. Bunker and Schuber have in this paper contributed a much needed addition to the literature on hydrogen ion concentration determinations and the reaction of culture media. In the words of our bacteriologist Dr. Straus, "We were making hydrogen ion determinations, but we really did not know exactly what it was all about until we read the paper.

We have used it for a reference and will welcome its appearance in print to keep it as such."

LINN H. ENSLOW.³

The so-called "1920 edition" of Standard Methods for the Examination of Water and Sewage is a reprint of the 1917 edition with few emendations. Consequently it is not surprising that the section on adjustment of reaction of media is unsatisfactory.

In the forthcoming revised edition of Methods for the Chemical Examination of Water and Sewage, which it is hoped to complete and submit at the November meeting of the American Public Health Association in New York, will appear methods for determining hydrogen ion concentration in connection with the discussion of methods for determining acidity.

It was the conclusion of the committee, after considerable discussion of the matter, that Standard Methods should confine itself strictly to methods, with a statement of essential definitions and of the limitations of the methods.

To enter fully into a presentation of elementary chemistry (and bacteriology) would entail an inordinate enlargement of the text with corresponding increase in cost of publication. Instruction of plant operatives in technique and interpretation of results is outside the province of the committee charged with the work of revision, and seems best left to the initiative of authors of text-books, class manuals, journal articles, and above all to personal contact with trained and experienced men.

W. F. MONFORT.⁴

This excellent paper is both full and timely. It deals with a subject very much "in the air;" one upon which many members of the American Water Works Association will welcome light. Even though a superintendent of a large city water-plant may depend upon his staff for expert knowledge as to how best to secure information regarding the bacterial condition of the water under his charge, nevertheless he should not be ignorant of the meaning attached to scientific terms likely to be used in his annual report. For the small works man, who of necessity must cover all portions of the plant work personally, familiarity with "What is meant by Ph" and "What

³ Assistant Engineer, State Department of Health, Richmond, Va.

⁴ Consulting Chemist, St. Louis, Mo.

is hydrogen-ion-concentration" must be rated as among the necessities. The authors have drawn together many very valuable data from widely scattered sources not within the reach of water-men outside of large cities and have added thereto most interesting experiences and observations of their own.

Inasmuch as to some who have to do with water examination it is not clear just why so radical a change should be made in the matter of determining and adjusting the reactions of culture media, the thought presents itself would it not have been well to have added to the excellent tables given just one more showing numerically the differences between the old and the new forms of reaction control as illustrated by the differences in results for the same water when employing first one and then the other method of preparing the culture media.

W. P. MASON.⁵

TAPPING LARGE STEEL MAINS⁶

Mr. O'Brien has called attention to the fact that tapping large steel mains is done in the same way that cast iron mains are tapped, except that there are some variations in getting the clamps that go around the pipe properly to fit the pipe, due to variations in diameter and projections on the surface of fabricated steel pipe. This difficulty will be largely done away with where lap welded steel mains are used, as welded pipe are cylindrical, uniform in diameter, and have no projections of any kind on their inner or outer surface. The uniformity of diameter is due to the process of manufacture in which the pipes are rounded up and straightened after the pipe is welded. For pipe of relatively large diameter and thin wall there is, of course, danger of the pipe settling slightly out of round when back filling has not been made in a manner properly to support the pipe.

F. N. SPELLER.⁷

INTERFERENCE OF WELLS⁸

It is noted in the paper by Messrs. Chester and Davis that, whereas the mean annual rainfall over the artesian outcrop amounts

⁵ Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.

⁶ This JOURNAL, p. 54.

⁷ Metallurgical Engineer, Pittsburgh, Pa.

⁸ JOURNAL, July, 1921, p. 377.

to 48 inches, only 15 per cent or 7.25 inches is assumed to percolate, though possibly this may make some allowance for flow into the river bed. In England, when dealing with chalk or sandstone areas, the percolation is almost invariably taken at 10 inches; the range in mean rainfall being from 25 inches to 45 inches. It is not often that such ideal conditions for the measurement of interference effects occur in practice, and it is useful to know in such uniform material as prevails under Memphis that theory agrees with practice. The radius at which no interference takes place—something over 3000 feet—is closely in agreement with the results obtained in wells in the Triassic sandstones, though here the occurrence of faults sometimes leads to apparently anomalous results. The writer knows of one case of a chalk water supply in which a copious yield was obtained from one boring and from another only 10 feet away, nothing at all. The explanation is that the only available water in the chalk is that which flows in the fissures, and these may be but a few feet apart or 5 or 6 feet, and the only way of ensuring an adequate supply is by means of adits to intercept the fissures. The conception of a radius of non-interference therefore in such formation as the chalk is one which must be used with caution and only with an adequate knowledge of the character of the material, the direction of major and minor fissures, and the geological structure of the district.

H. J. F. GOURLEY.⁹

COLLOIDAL CHEMISTRY AND WATER PURIFICATION¹⁰

Mr. Stein's paper contains an abundance of matter that requires careful examination and will serve the useful purpose of compelling us to consider critically the indictment as to the relation of water purification to colloidal chemistry.

The writer believes that the rôle of mass action has long been recognized but that this phase of physical chemistry was found to be insufficient to explain the whole of the phenomena involved. This is well illustrated by the facts given in the earlier part of the paper. In distilled water, it is stated, the reaction of alum and alkali is slow but in turbid water "the reaction is much more rapid, and the coagulation is good and settlement rapid." If the kaolin suspension

⁹ Sir Alexander Binnie, Son and Deacon, Victoria Street, London, England.

¹⁰ JOURNAL, November, 1921, p. 571.

is inert, as is generally admitted, the law of mass action requires that the reaction velocity is identical in both cases. Chemical action ceases at this point and we have next to consider the physical state of the reaction products. Colloidal chemistry provides a satisfactory explanation of the subsequent phenomena and to this extent at least the science of water purification is indebted to the colloidal hypothesis.

Much unnecessary confusion has arisen through the indiscriminate use of reaction and visible reaction as interchangeable terms. The alum-alkali reaction according to the writer's experiments is a rapid one but the visible reaction may be nil or comparatively rapid. When alum is added to the Ottawa River water the visible reaction occurs in about 30-45 minutes, but if the water is filtered through paper immediately after the alum is added, the color is removed. This is not conclusive proof that the reaction is practically instantaneous but it is much more probable than that the filter paper accelerates the reaction.

Colloidal chemistry does not explain the difficulties encountered with many waters but on the whole the colloidal hypothesis is a definite advance on previous ones and will be used until new facts provide a more rational one. At present the cases which it does not explain satisfactorily are due probably to our inadequate knowledge of the various colour colloids found in water. Mr. Stein takes tannates and gallates as being typical of the complex substances present, but if this were true there should be a greater correlation between the colour and the iron content than is usually found. Humic, ulmic and other acids are often present in coloured water and these form brown colloidal solutions with ammonia, magnesia, and lime.

The coagulation and removal of colour from waters cannot be explained by any single branch of physical chemistry. Mass action explains part of the phenomena; colloidal chemistry another part; and ionisation and dissociation still another part. All must be considered collectively if we are to obtain a better understanding of the process known as coagulation.

JOSEPH RACE.¹¹

¹¹ Hereford House, England.

SHORTCOMINGS IN THE PRESENT STANDARD METHODS OF WATER ANALYSIS FROM THE OPERATOR'S VIEWPOINT

Mr. Birdsall's criticisms¹² of the present standard methods of water analysis appear to divide themselves under two main headings.

In the first place Mr. Birdsall desires an expansion of the standard methods report so that it will give more detailed information in regard to certain points in sampling and analysis. With these criticisms I find myself heartily in accord. It would certainly be most helpful to include in a new edition of the standard methods data bearing on such points as the formula for cleaning solutions, the exact method of collecting a water sample, and the procedure in determining color, and the like. There are also certain specific changes in the present procedures suggested by Mr. Birdsall which should receive the most careful consideration. I am personally strongly in sympathy with the substitution of hydrogen-ion determinations for the old method of titration just as soon as the laboratory workers of the country are ready to support such a step.

A second group of modifications suggested by Mr. Birdsall seem to raise a question of a very different kind. These are the suggestions which look toward the inclusion in the standard methods report of statements bearing on the interpretation of the results obtained. It is possible as Mr. Birdsall has pointed out to train a laboratory worker who has no extensive preliminary background to perform routine analytical work and he should have the fullest directions to enable him to do so. When it comes to interpretation, however, I think short cuts are exceedingly dangerous. We have suffered too much in the past from the attempt to use arbitrary yardsticks of various sorts in sanitation and the plain truth is that no one can learn to interpret chemical and bacteriological examinations of water without a very careful study of such detailed textbooks as are now available. It would be absurd in a report on standard methods to reprint these textbooks on the fundamental principles of water bacteriology and water chemistry and anything short of such a full presentation would merely lead to a fallacious and dangerous assumption of non-existing knowledge. Analyses can be performed by an imperfectly trained laboratory worker but they can not be safely interpreted by anyone who is not really a

¹² This JOURNAL, page 56.

master of the subject. I believe therefore that the committee on standard methods has been very wise in avoiding the attempt to deal with the interpretation of results in any condensed form.

C.-E. A. WINSLOW.¹³

PROGRAM FOR ANNUAL CONVENTION

The program for the annual Convention at Philadelphia is now being prepared. Suggestions regarding topics for discussion and particularly regarding papers on any phase of water supply are invited. Members are urged to send these suggestions at once to the Chairman of the Publication Committee, Robert B. Morse, Chief Engineer, Maryland State Department of Health, 16 West Saratoga Street, Baltimore, Md.

¹³Anna M. R. Lauder Professor of Public Health, Yale University, New Haven, Connecticut.

SOCIETY AFFAIRS

CANADIAN SECTION

A meeting of the Canadian Section was held at Niagara Falls, Ontario, June 4, 1921. The report of a special committee appointed at the last meeting, February 4, 1921, on fire protection, where connection is made with a city main, was read by Alexander Milne, chairman of the Section, and was discussed by C. D. Brown, G. G. Powell, W. H. Randall, and A. Milne.

In the afternoon a luncheon was held, at which Mayor Stevens of Niagara Falls, Ontario, spoke in brief, welcoming the members to the city. The luncheon was followed by a paper on "The Water Supply on the Niagara Frontier," by Dr. R. C. Snowden, chemical engineer with the Hooker Electrochemical Company of New York. The paper was discussed by F. A. Dallyn, C. D. Brown, F. W. Frank, A. U. Sanderson, N. J. Howard, H. G. Hunter, J. J. Salmond, and the author.

A paper by F. A. Dallyn, on the "Water Supply of the Niagara Peninsula," was not presented on account of the lateness of the hour. The manager of the *Canadian Engineer* agreed to print it at once to make it available to the members.

It was decided to hold the next annual meeting at Brantford, Ontario. The date is to be determined by the Executive Committee. Considerable sentiment appeared in favor of a mid-winter meeting. The place and date for such a meeting were left to the decision of the Executive Committee.

The following officers were elected for the coming year: Chairman, R. C. Harris; vice-chairman, H. G. Hunter; secretary-treasurer, C. D. Brown; trustee, J. J. Salmond.

IOWA SECTION

The seventh annual convention of the Iowa Section was called to order in the ball room of the Hotel Castle, Omaha, Nebraska, by Chairman Frank Lawlor, at 10:00 a. m., November 1, 1921. An address of welcome on behalf of the City of Omaha (in the absence of Mayor James C. Dahlman) and of the Metropolitan Utilities

District, was made by Mr. Fred D. Wead, Chairman, Metropolitan Utilities District, Omaha. Chairman Frank Lawlor responded.

The following topics were discussed after the addresses:

"Proper Charges for Hydrant Rental." Discussion opened by C. L. Ehrhardt, City Engineer, Boone, Iowa, followed by William Molis, Muscatine, Iowa; Charles R. Henderson, Davenport, Iowa; F. P. Larmon, Omaha, Nebraska; F. D. Wead, Omaha; Peter Kern, Fort Madison, Iowa; Ed. Brown, Eau Claire, Wisconsin; F. B. Gallagher, Independence, Missouri; F. M. Johnson, Terre Haute, Indiana; C. D. Robison, Omaha; and closed by C. L. Ehrhart.

"Charges for Depreciation of Water Works Systems." Discussion opened by C. L. Ehrhart, Boone, Iowa; followed by F. P. Larmon, Omaha; R. H. Holbrook, Cedar Rapids, Iowa, and C. D. Robison, Omaha.

It was moved by C. L. Ehrhart and seconded by R. H. Holbrook that the Legislative Committee take up the matter of the proper protection of depreciation funds built up by water departments. The motion was carried.

"Routine Analyses for Water Plants." Discussion opened by J. J. Hinman, Jr., Iowa City, Iowa, followed by C. A. Jennings, Chicago, Illinois; R. H. Holbrook, Cedar Rapids, Iowa; H. V. Pederson, Des Moines, Iowa; R. N. Tracy, Lincoln, Nebraska; W. A. Hendry, Waterloo, Iowa; H. V. Knouse, Omaha, and the discussion was closed by J. J. Hinman, Jr.

"Placing and Locating Gates on Water Mains." Discussion opened by William Molis, Muscatine, Iowa; followed by H. V. Knouse, Omaha; C. R. Henderson, Davenport, Iowa; F. W. Johnson, Terre Haute, Indiana, and C. L. Ehrhart, Boone, Iowa.

"Iron in Water Supplies." Discussion opened by J. J. Hinman, Jr., Iowa City, Iowa; followed by Ed. Brown, Eau Claire, Wisconsin; and C. A. Jennings, Chicago, Illinois.

The meeting adjourned at 12:00 noon for luncheon. The attendance at the session was 30.

The Section reconvened at 2:00 p. m. when the following papers were presented:

"A Facultative Spore-Forming Lactose-Fermenting Bacillus from Iowa Surface Waters. (*B. macerans*?)," by Jack J. Hinman, Jr., and Max Levine. The paper was discussed by William Molis of Muscatine, Iowa, and R. N. Perkins of Omaha, Nebraska.

"Does Bile Inhibit or Stimulate the Growth of the Colon Group?" by Max Levine. The paper was discussed by R. N. Perkins of Omaha.

The round table discussions were again taken up as follows:

"Screening Equipment for Removing Debris from Intake Water." Discussion opened by S. L. Etnyre, Council Bluffs, Iowa; followed by Frank Lawlor, Burlington, Iowa; R. H. Holbrook, Cedar Rapids, Iowa; H. P. Letton, Lincoln, Nebraska; and J. J. Hinman, Jr., Iowa City, Iowa.

"Iron Removal by Aeration." Discussed by R. W. Wallis, Ames, J. J. Hinman, Jr., Iowa City, Iowa; H. P. Letton, Lincoln, Nebraska; and T. C. Messplay, Omaha.

"Type of Valve Box and Packing for Street Valves." Discussed by H. V. Knouse, Omaha; William Molis, Muscatine, Iowa; S. L. Etnyre, Council Bluffs, Iowa, and A. E. Jones, Chicago.

Frank Lawlor then read a resolution prepared by C. R. Henderson of Davenport on the subject of automobile pumpers. The resolution was referred to the committee on resolutions when such committee is named.

The session then adjourned. Attendance at session, 45.

In the evening, at 8:00 o'clock, the Section was entertained with a smoker by courtesy of the local members of the Association and the manufacturers' representatives.

The session was called to order on Wednesday, November 2, by Chairman Lawlor at 10:15 a. m. to listen to the reading of papers given below:

"Sanitary Control of the Krug Park Swimming Pool" by R. N. Perkins. The paper was discussed by C. A. Jennings, Chicago; J. J. Hinman, Jr., Iowa City, Iowa; and Edward Bartow, Iowa City, Iowa.

"The Disinfection of Water Supplies and its Relation to the Public Health," by C. A. Jennings, Chicago. The paper was discussed by Frank Lawlor, Burlington, Iowa; Edward Bartow, Iowa City, Iowa, and William Molis, Muscatine, Iowa.

"Methods of Treatment of Missouri River Water" by S. L. Etnyre, Council Bluffs, Iowa.

The session was adjourned to meet again at 3:00 p.m. for the reading of additional papers.

The members of the Section proceeded by automobile to the Broadway Pumping Station of the Council Bluffs City Water Works

where an excellent luncheon was served by the courtesy of the Trustees of the Council Bluffs Water Works. Following the luncheon the members of the Section posed for a photograph on the lawn of the plant. An inspection trip around the Broadway Station and a trip to the River Pumping Station on the banks of the Missouri River was taken where the members of the party had an opportunity to see the present methods of treating the water and to inspect the new basins under construction at that point.

The reading of papers was resumed at 3:00 p.m. in the following order:

"The Cement Gun in Water Works Practice" by L. R. Talbot. Frank Lawlor, Burlington, Iowa, and S. L. Etnyre, Council Bluffs, Iowa, discussed the paper.

"Water Softening as a Factor in Municipal Supply" by W. M. Barr, Nebraska. Joseph B. Thornell, Council Bluffs, Iowa; Edward Bartow, Iowa City, Iowa; T. C. Messplay, Omaha; and S. L. Etnyre, Council Bluffs, Iowa; discussed the paper.

Chairman Lawlor then announced the membership of committees as follows:

Auditing Committee: R. H. Holbrook, Cedar Rapids, Iowa, and R. N. Perkins, Omaha, Nebraska.

Resolutions Committee: Ed. Brown, Eau Claire, Wisconsin; R. N. Tracy, Lincoln, Nebraska; C. S. Burns, Kansas City, Missouri; C. L. Ehrhart, Boone, Iowa.

Nominations Committee: Chas. R. Henderson, Davenport, Iowa; Edward Bartow, Iowa City, Iowa; William Molis, Muscatine, Iowa; Homer V. Knouse, Omaha, Nebraska.

The session adjourned and the members, by courtesy of the Omaha Fire Department, were enabled to see an exhibit of representative units of equipment which were drawn up in front of the hotel.

The Auditing Committee, through R. H. Holbrook, reported that they had gone over the books of the Secretary-Treasurer and found them correct. The report was unanimously accepted.

The following officers were elected: Chairman, J. Chris Jensen, Council Bluffs, Iowa; Vice Chairman, Peter Kern, Ft. Madison, Iowa; Director, Harry P. Letton, Lincoln, Nebraska; Director, C. L. Ehrhart, Boone, Iowa. The Executive committee reappointed J. J. Hinman, Jr., Iowa City, secretary and treasurer.

The question of transferring the date of the meeting of the Section from the fall to the spring in order to fall in line with the plan

of holding an intersectional meeting, as was done at Chicago since the last meeting of the Section, was referred to the Executive Committee with power to act, with the provision that Messrs. Bartow, Henderson, Molis, and Knouse be consulted before action was taken.

Charles R. Henderson of Davenport, Iowa, then presented a resolution on the use of automobile pumpers for raising fire pressure. It was discussed by C. S. Burns, Kansas City, Missouri; Homer V. Knouse, Omaha and S. L. Etnyre, Council Bluffs, Iowa; and C. R. Henderson. The resolution was finally unanimously adopted in the following form:

WHEREAS, there are serious objections to the practice of raising water pressure on systems of water mains at time of fire,

AND WHEREAS, the increase of pressure in itself results in more water being discharged through the numerous leaks which always exist and more water being used through fixtures, in damage to plumbing, in the breaking of service pipes, and, at times, the breaking of large water mains, all at a time when the whole water supply should be strictly conserved,

AND WHEREAS, accidents to pumping machinery and valves are more apt to occur, and do occur, under the additional strain and during the excitement of raising fire pressure,

AND WHEREAS, increased pressure ordinarily requires that water stored in elevated reservoirs be shut off during fires, and so made unavailable, in order to permit of direct pumping into the mains, resulting in an extra burden being placed upon filter plants, and consequent danger of an epidemic following a conflagration,

AND WHEREAS, in handling fires in high buildings, and in the case of other serious hazards, fire departments now require larger and more powerful streams far beyond the capacity of domestic water works systems to supply,

AND WHEREAS, such streams and such pressure can be furnished by motor pumpers without the hazard of raising pressure in the city mains, making more and shorter lines of hose available without the heavy expense for equipment and operation formerly required in the case of steam fire engines,

THEREFORE, BE IT RESOLVED, by the Iowa Section of the American Water Works Association, in Convention at Omaha, that we recognize the hazard and expense incurred in raising fire pressure in domestic mains, and we declare it as our opinion that such method constitutes an undesirable practice, and that the practice of raising fire pressure by means of motor pumpers or other auxiliary apparatus should be extended as rapidly as possible, as being more suitable, more economical, and in the best interest of the whole people.

Forty-six persons attended the banquet of the Section at the Hotel Castle. Chairman Lawlor acted as toastmaster. The speakers were as follows:

Hon. James C. Dahlman, Mayor of Omaha.

Hon. John Lee Webster, Attorney, Metropolitan Utilities District, Omaha.

Dr. Edward Bartow, President of the American Water Works Association.

Chairman Lawlor called the session to order at 9:45 a.m. on Thursday, November 3. The following papers were read:

"Fighting Algae with Copper Sulphate and Chlorine" by Charles R. Henderson, discussed by Edward Bartow, Iowa City; William Molis, Muscatine, Iowa; W. A. Hendry, Waterloo, Iowa; and R. N. Tracy, Lincoln, Nebraska.

"Water Purification in Iowa," by Jack J. Hinman, Jr., with lantern slides.

"The Omaha Water Plant" by Frank P. Larmon.

This completed the formal program of the convention which was then adjourned.

In the afternoon the members of the Section were taken by automobile to the Minne Lusa Pumping Station of the Metropolitan Utilities District of Omaha at Florence, Nebraska.

CALIFORNIA SECTION

The second annual meeting of the California Section was held at Los Angeles on October 1 and 2, 1921. There was an attendance of seventy-two from all parts of the State.

The following papers were read:

"Fire Protection," by R. E. Andrews, Asst. Chief Engineer, National Board of Fire Underwriters, printed in this issue of the Journal.

"Causes and Prevention of Electrolysis Troubles in Underground Pipe Systems," prepared by E. B. Stewart, and read by H. Reinhardt, Asst. Chief Engineer, East Bay Water Company, Oakland.

"Water Meters," by Geo. Reed, Supt. Service and Meter Department, Los Angeles.

All of the papers were freely discussed. The remainder of the time was spent in general discussion of waterworks problems, in which a great number took part. Dinner was served at the City Club of Los Angeles, after which Mr. Wm. Mulholland, Chief Engineer of the Los Angeles Bureau of Water Works and Supply gave an interesting talk on the Los Angeles Water Supply.

On October 2 a trip was taken to the points of interest in the Los Angeles water works system. Luncheon was served in the construction camp at the San Fernando Dam.

The following officers were elected for the coming year: Chairman, G. A. Elliott; vice-chairman, L. M. Anderson; secretary-treasurer, Geo. W. Pracy. The additional members of the executive committee are C. G. Gillespie and F. N. Isaacs.

MINNESOTA SECTION

The tenth meeting, on November 4, 1921, was the best ever held by the Minnesota Section, both from the standpoint of interest shown in the meeting and of the number in attendance. The presence at the meeting of the national president, Dr. Edward Bartow, undoubtedly created unusual interest in this meeting and brought out the record attendance of 54.

Dr. Bartow spoke of the advantages of membership in the American Water Works Association and emphasized the need for increasing the membership, if the Association is to continue the program already undertaken for increasing the benefits to its members.

Dr. H. E. Robertson of the Mayo Clinic and Professor of Pathology at the University of Minnesota presented an interesting paper replete with new ideas for consideration by waterworks men. This paper is printed in this issue of the JOURNAL. An interesting discussion of the paper followed its presentation. One physician present called attention to the prevalence of goiter at Akron, Ohio, as stated in an article published in the Journal of the American Medical Association for October, 1921. The whole discussion demonstrated the need for a closer relationship between the medical profession and the water works men in solving some of the newer problems of public health.

Dr. H. E. Barnard, Director, American Institute of Baking, Minneapolis, read an interesting paper on the subject of "The Mineralization of Waters with Respect to their Fitness for Commercial Use."

Mr. C. A. Jennings, Wallace and Tiernan Company, Chicago, Ill., presented a paper, illustrated with lantern slides, on the subject of "The Disinfection of Water Supplies and Its Relation to Public Health."

The afternoon session was devoted for the most part to the presentation and discussion of subjects that were of general interest. A few subjects for discussion were printed on the program and other questions were suggested by those present.

The whole program was designed to interest those who were attending the sessions of the Minnesota Public Health Association, the State Sanitary Conference, and the Minnesota Educational Association, which meetings were held simultaneously at the University of Minnesota. The meeting of the Minnesota Section was a part of the general Health Conference.

The Section voted to hold its spring meeting at the same time and place as the League of Minnesota Municipalities, at Crookston in June, 1922. It was also voted to hold the 1922 fall meeting at the same time and place as the next State Health Conference. It is possible in this way to disseminate information concerning the waterworks field to a much larger group of persons and thus to increase materially the membership of the Minnesota Section.

The death of Mr. F. W. Cappelen, City Engineer of Minneapolis, formerly a Trustee of the American Water Works Association, and first Chairman of the Minnesota Section, occurred on October 16, 1921. A Committee was appointed to draw up suitable resolutions for publication in the JOURNAL. The report of this committee was accepted and a copy of the resolutions was ordered to be sent to Mrs. Cappelen.

ABSTRACTS OF WATER WORKS LITERATURE

Double Check Values. Eng. News-Rec., July 7, 1921. Hartford, Conn., voted, in 1920, to abolish and prohibit all connections between the public water supply and other sources of supply, including double check valve connections of all kinds.—*J. N. Chester.*

Electrolysis. Eng. News-Rec., July 7, 1921. Conditions relieved in Winnipeg by three-wire system for electric railway, reducing cable drainage current over 60 per cent.—*J. N. Chester.*

Friction Loss in Spiral Pipe.—Eng. News-Rec., July 28, 1921. Experiments at Purdue University show that the friction loss in galvanized, spiral riveted, steel pipe is nearly the same as for smooth cast iron pipe when the flow is with the laps. Spiral pipes should be laid so that the flow is with the laps.—*J. N. Chester.*

Manning and Kutters Formulae. Eng. News-Rec., July 21, 1921. Study of gagings in Chicago Sanitary District indicates "Manning formula better than Kutters" for 'n' except when 's' terms omitted.—*J. N. Chester.*

Tastes in Marquette, Mich. water. Eng. News-Rec., July 14, 1921. Investigations show that tarry waste products from wood alcohol manufacturing create the offensive tastes in Municipal water at Marquette, Mich. Removal at source only practical solution and the company is preparing to convert tar wastes into liquid fuel by evaporation to 25 per cent.—*J. N. Chester.*

Treatment of Water Gas Waste. Eng. News-Rec., August 4, 1921. Water gas wastes at Flint, Mich., have been treated experimentally with lime as a coagulant, removed through coke filters.—*J. N. Chester.*

Five Years Sanitary Progress. West Virginia State Board of Health-Reports. Report for 1915-1920 shows marked reduction in typhoid toll by chlorination and further reduction by filtration and chlorination. 1919-1920 Annual Report, gives a history of the State Board of Health, since established in 1881.—*J. N. Chester.*

Rural Water Supplies. Mississippi State Board of Health, Health Bulletin, Special Bulletin No. 16. The paper sets forth in simple manner the means of securing pure water supply and of safeguarding the same against contamination. Drawings are given illustrating satisfactory and unsatisfactory conditions. The diseases which are most apt to be water-borne in Mississippi are typhoid fever, various types of dysentery and diarrheas, and several varieties of intestinal worm infections or parasitic diseases. Common among this latter class are the ordinary round worm, or stomach worm, the hook worm, the parasite causing amoebic dysentery, etc.—*A. L. Fales.*

Milwaukee Water Supply. H. P. EDDY. Eng. News-Rec., July 7, 1921. On Milwaukee controversy, Mr. Eddy urges immediate plans for water purification plant regardless of new sewage works because of storm over-flows and other contamination not controlled by sewage plant. Recommends labora-

tory investigations in colloidal chemistry, which might reduce capacity requirements for coagulation and filtration.—*J. N. Chester.*

Report of Division of Water and Sewage. Montana State Board of Health, Report for the Years 1919 and 1920. W. N. COBLEIGH. Based on field inspections and analyses the public water supplies are classified as "approved" or "unapproved." Definite recommendations for improvement, are made for the latter class. There are 112 public water supplies in the state, of which 42 are owned by private companies and 70 by municipalities. Of the total supplies, 19 have not yet been classified. Of the remaining, 14 were approved and 15 more have now been approved because of the installation of purification plants. The classification of 6 purification plants has been deferred pending the making of recommended improvements. Of the purification plants one has filtration only, 8 have filtration and disinfection with liquid chlorine, and 16 have only disinfection. Plans and specifications for proposed water systems were received from 13 municipalities. A total of 31 drinking water supplies for common carriers are examined every six months.—*A. L. Fales.*

Evaporation from Gatun Lake, Panama Canal Zone. J. E. HUGHES. Engineering and Contracting, August 10, 1921. Approximately 62 inches evaporate from Gatun Lake surface in a calendar year. During the dry season from January 1 to May 1, 1921, the evaporation amounted to 24.46 inches. The method of measuring rainfall and evaporation is described in detail.—*A. L. Fales.*

The Production of Wholesome Water for Municipalities. LEWIS O. BERNHAGEN. Texas Bur. San. Eng. Pub., November 4, 1920. The purpose of this pamphlet is to present in condensed form information which will be of assistance to the operators of water filtration and sterilizing plants where no regular chemist or bacteriologist is in attendance. It deals with the collection of samples, methods of analysis and interpretation of results, sources of supply, construction and operation of mechanical filter plants and chlorination apparatus. An appendix of useful information is given.—*A. L. Fales.*

Report on Examination and Control of Water Supplies. CHARLES B. HOWARD. New Hampshire State Board of Health, Report for Fiscal Years of 1919 and 1920. The total number of water samples examined during the two years amounted to 1939 of which 849 were from public systems, 230 from sources of public interest furnishing water to factories, hotels, schools, etc., and 860 from private sources. Of the latter approximately two-thirds failed to represent water of entirely acceptable quality, due in large measure to failure to keep the source clean, or to the entrance of surface drainage. Of 33 railroad supplies requiring certification to the U. S. Public Health Service, two were condemned and discontinued. The total number of supplies subjected to purification treatment on September 1, 1920 was 13, including 7 filtration plants of which five have chlorination, and five plants using chlorination only, of which two use hypochlorite instead of liquid chlorine. Improvements are advised for several treatment plants and treatment is recommended for 5 supplies not now treated. With reference to connections with polluted secondary supplies at factories, the Department insists on two checks in series of approved construction, installation in such manner as to be readily accessible for examination and test, and inspection as to working

condition at least twice annually. The Department has uniformly required that the supply for drinking and ablutionary purposes for the operatives, shall be from a special line from the street main, independent of the fire system.—*A. L. Fales.*

Water Softening and Purification at Columbus. Public Works, August 13, 1921. Typhoid death rate reduced more than 90 per cent by the introduction of filtered water. Charles P. Hoover, chemist, has been experimenting with addition of acids to the softened water to reduce its tendency to form incrustations on the filter sand and in the distribution system. The addition of 0.7 grains per gallon to the water of phosphoric acid made by boiling Tennessee rock phosphate in sulphuric acid is now being tried on a large scale.

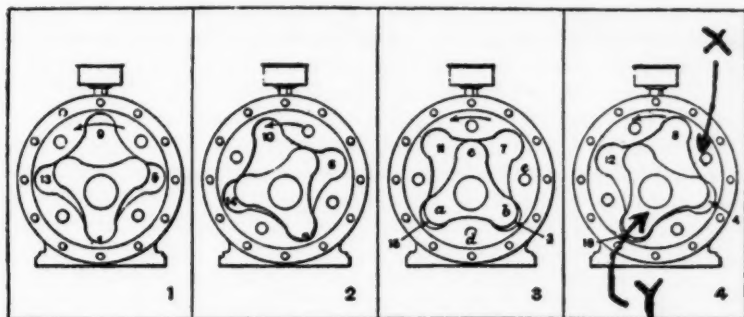
Water Waste Control. Eng. News-Rec., August 4, 1921. By partly closing during the night, all main valves on the distribution system, London, England, the water consumption was reduced 12½ per cent.—*J. N. Chester.*

Engineering Developments in British South Africa. R. A. LUNDQUIST. Bull. Minnesota Federation of Arch. and Eng. Soc. Aug., 1921. Although water service is available in the larger towns, the supply is generally short and restrictions are placed upon its use. Very little attention is given to the question of purity and in most cases it is unsafe to drink the water until boiled.—*A. L. Fales.*

Illinois State Department of Public Health, Annual Report, 1919-1920. Division of Eng. and Sanit. HARRY F. FERGUSON. The activities of the Division in the examination of water supplies and investigations and advice relative to existing or proposed supplies, including purification plants, are described. The work of examination and certification of water supplies, for the United States Public Health Service, used on interstate common carriers, has been extended to include intrastate carriers, also, and attention has been given to the method of handling the water from the sources to the car tanks. During the fiscal year 83 places in which one or more watering points are located, were inspected, and 693 samples analyzed. This work has brought about improvement in many private sources of water supply as well as calling attention of officials to defects in public water supplies. The most important investigation of water-borne epidemic, in which the Division coöperated with the Division of Communicable Diseases, was the outbreak of typhoid fever which occurred among the employes at the shops of the Chicago and Alton Railroad at Bloomington. This epidemic which comprised over 200 cases, with 24 or more deaths, was due to interconnection with a contaminated water supply. This interconnection was abandoned and a new distribution system installed.—*A. L. Fales.*

Exeter Rotary Pump. Nautical Gazette, 101, 19, 597-609. May 7, 1921. The Exeter Rotary Pump built under the Feuerheerd patents has two rotating elements, an outer four lobe rotor X, driven by an inner three lobe rotor Y, set eccentrically to it. The irregular spaces between the two rotors increase and decrease in volume as the two rotate at slightly different speeds, and are utilized to admit and eject the fluid.

The pump has no valves, and being of the positive displacement type, is self priming. While the contact between the two rotors is of a rolling nature the pump has a large bearing surface between the outer rotor and the casing,



CYCLE OF MOVEMENT OF THE ROTORS OF THE EXETER PUMP

and close clearances must be maintained between the sides of the two rotors and the casing in order that the pump may function properly. For handling viscous liquids, oils, etc., this type of pump should find a considerable field of application.—*L. A. Quayle.*

Metropolitan Water Supply for the Twin Cities. JOHN W. KELSEY. Bull. Minnesota Federation of Arch. and Eng. Soc., 6, 9, September, 1921. After considering available surface and ground water supplies the author concludes that main dependence should not be placed upon a well water supply, because of its hardness, the high cost of pumping and distribution, and the danger of such a supply becoming inadequate. From an economical standpoint he believes the only method of securing a metropolitan water supply would be to use the Mississippi River water. In his opinion the advantages of such a metropolitan supply, over independent supplies for the two cities, are offset by the disadvantages.—*A. L. Fales.*

Financing Municipal Water Supplies. W. D. P. WARREN. Illinois Soc. of Eng., Annual Report, 1921. The State of Illinois has 12 cities with more than 2000 population and more than 600 cities and villages of less than 2000 population, without a public water supply. The author believes that a satisfactory water supply should be possessed by each city having a population over 1000 and by many smaller cities where the supply can be obtained without excessive cost. During the past few years few supplies have been installed and extensions to existing supplies have been inadequate in many places. At many plants the supply is of unsatisfactory quality and modern water purification plants are greatly needed. With the cost of materials high and the bonding capacity of many cities insufficient to meet the expense of proper improvements, the situation has become acute. A plan of securing an adequate water supply in a few cities has been brought about by a willingness on the part of local parties to invest in the securities of a water supply company formed for the purpose, or to assume responsibility otherwise for the payment of funds necessary to construct the improvement. The plan of three cities is described in detail.

The schemes considered by Ralph J. Monroe, Corporation Counsel for Decatur, are as follows: By a statute in 1899, the state authorized the con-

struction or purchase of a water plant by a city and the issuance of water certificates bearing interest and secured by mortgage on the property constructed or purchased and payable out of the income of the property and from no other source. This method of financing is satisfactory only in cities which have no plant at all to begin with. All other schemes of financing municipal water supplies where the city is close to its debt limit, depend upon private capital, some of the common forms being, (a) Organization of a water supply company to construct and operate the plant, (b) Trustees to sell trustee certificates, purchase the property and lease it to the city, and (c) Contract with the construction company to build the plant and sell it to the city on a conditional sales contract. The first of these three plans is very desirable where it can be used, and forms the basis of the plan at Decatur. It has an advantage over the municipal water certificates first-mentioned, in that the corporation will hold the title to the property until paid for, and no foreclosure would be required. The trustee arrangement is the one commonly used and is very satisfactory except that if the investment is sufficiently large, inasmuch as the courts have indicated that the payment payable in any one year is a debt, it might be that the amount payable in any one year would in itself be a violation of the debt limit. This can be avoided by adding the quarterly installments payable in advance, as in the Decatur plan. The plan of letting a construction company build the plant has the advantage that such an agreement relieves the city administration and citizens from the worry and work of financing, but this relief will be dearly paid for as the contractor must be well paid for the risk and he will figure on a high discount rate. However, as a last resort the plan is better than none.

In view of the difficulty of putting any of these methods into practice in some municipalities, the author suggests that the legislature pass an act to create water districts, this act to be patterned after that passed by the Illinois Legislature in June 1917, to create sanitary districts and to provide for sewage disposal.—*A. L. Fales.*

Further Observations on Ph in Natural Waters. ABEL WOLMAN. AND FRANK HANNAN. *Chem. and Met. Eng.* 25, September 14, 1921. The article contains a valuable review of the recent scientific literature on the subject of hydrogen ion concentration and a discussion of the applications to be made to the problems of water purification. The experimental part includes observation on the hydrogen ion concentration of Lake Ontario water over a period of eleven months as well as similar data upon slow sand and mechanical filtration plants. The relations of temperature, pollution and filtration with hydrogen ion concentration are discussed.—*A. M. Buswell.*

Bactericidal Action of Water Treated by Ultra-Violet Rays. W. F. WALKER. AND R. W. PRYER. *American Jour. Pub. Health*, 11, 8, 701, August, 1921. The authors describe experiments conducted by them at Detroit, from which they conclude that the exposure of water to ultra-violet light emitted from a quartz mercury vapor arc, imparts to the water a definite residual bactericidal property which effects a reduction of at least 85 per cent of the organisms subsequently added, this property being dependent upon the energy input into the lamp and the time of exposure and accentuated in series installations. The

usual pressure type of sterilizer operating on a 220-volt current develops the bactericidal property under ordinary working conditions.—*A. L. Fales.*

Report of Bur. San. Eng. June, 1921. California State Board of Health, Monthly Bulletin, 17, 2, August, 1921. This report lists the sanitary improvements being carried out by various California cities, and gives a summary of the Bureau's activities. Of special interest is a note relative to a case of arsenic poisoning traced to a spring the water of which gave a strong arsenic reaction.—*E. S. Chase.*

Typhoid Fever More Prevalent than in 1920. Illinois State Department of Public Health, Health News, 3, 10, October, 1921. Reports to the State Department of Public Health show an increase of typhoid over 1920, during June, July and August. The results of a large number of investigations indicate that much of the typhoid fever has been due to carriers.—*E. S. Chase.*

Chlorinated Water Not the Cause of Death of Citizen. Department of Health of the State of New Jersey. Public Health News, 6, 10, September, 1921. A résumé of a report of C. A. Emerson, Jr., Chief Engineer of the Pennsylvania Dept. of Health. A citizen of West Grove, Pa. died after an illness of a few hours and a coroner's jury after hearing the testimony of the attending physician, which included the fact that the decedent had drunk copiously of the chlorinated water from the public water supply, rendered a verdict that the death was caused by "general systemic debility caused by chemicalized water which produced a severe gastroenteritis followed by cardiac failure." The Commissioner of Health of Pennsylvania ordered the body to be disinterred and a postmortem made. The finding of the autopsy and a re-hearing of the evidence relative to the death, resulted in the coroner's jury bringing in a supplemental report as follows: "That chlorine was neither directly nor indirectly the cause of death; that death was due to acute dilatation of the heart sequential to the loss of bodily fluids incident to a severe attack of toxic gastroenteritis with complicating extensive cardio-vascular and renal degeneration." The evidence showed that over-exertion was the real cause of the death and that the decedent would have had to have drunk two quarts of the public water supply to have received even 1/80th of an additional dose.—*E. S. Chase*

Typhoid Fever Epidemic in Jacobstown, Burlington County, N. J. Public Health News, N. J., 6, 10, September, 1921. An account of a typhoid fever epidemic of 186 cases among about 400 persons who attended a Harvest Home Supper. The infection was contracted as a result of eating chicken salad served at the supper. The manner in which the salad was infected was not determined. This epidemic indicates the high ratio of cases to exposures (1 : 2) resulting from a typhoid infection of food, compared with that of one of the severest water-borne epidemics, that of Plymouth, Pa., when the ratio of cases to that of exposed population was about 1 : 8.—*E. S. Chase.*

State Board of Health of Rhode Island, Bull. 8, 2. Water Supplies Number, June, 1921. This bulletin deals with the activities of the State Board of Health in safeguarding the public water supplies of Rhode Island. This work, carried out by the Division of Chemistry and Sanitary Engineering, Mr. S. de M. Gage, Director, consists of monthly analyses of all surface waters and some of the ground water supplies, together with bimonthly analyses of

certain of the more important filtered supplies. There are 61 points from which samples are obtained for examination. Inspections are made yearly of all water supplies and at least once a month of all water filter plants. Reports and advice are given to the local authorities in charge of water supplies, and special studies and investigations are made upon request. This work is not carried out under specific legal authority and there is no compulsion for water works officials to carry out the recommendations of the Board.

All of the cities and 23 of the 33 towns in the State are provided with public water supply systems, so that approximately 90 per cent of the entire population have access to public water supplies, while the remaining 10 per cent, or 60,000, are dependent upon private wells, springs, etc., many of which are undoubtedly of questionable sanitary quality. It is interesting to note that 7 of the 10 towns without public water supplies are over 1000 in population. Another interesting fact is that only four of the public water supplies are owned by the municipalities they serve.

The water consumption of those places for which there are records, range from a minimum of 33 gal. per capita daily in two strictly domestic supplies, to 210 gallons per capita daily where four-fifths of the water pumped is used for manufacturing, and one supply of a mill town has a consumption of 360 gallons per capita daily. The average consumption per capita for the entire population served, was 82 gallons per capita daily. This bulletin describes in a general way the facts to be considered in basing judgment on the character of water supplies, and concludes with a comparatively detailed description of the various public water supplies of the state. No analyses, however, accompany these data.—*E. S. Chase.*

Sacramento Water Supply. J. R. SNEIDER. *American Jour. Pub. Health.* 11, 25, 11. November, 1921. The Sacramento River, with a drainage area of 23,400 square miles, has been the principal source of water supply for Sacramento City, since 1850. In the early years the supply was relatively free from contamination, but mining, agriculture and summer visitors upon the watershed have resulted in considerable contamination and marked deterioration in the physical quality of the river water. Typhoid fever has been prevalent. The average death rate 1891 to 1914 was 53.5 per hundred thousand. Since 1915 when the chlorination plant was installed, but 9 cases have been traced to the water supply. This paper, however, does not give the actual death rates since 1915.

Rice cultivated in the valley above the city, has affected seriously the quality of the water, due to drainage from rice fields, and the quantity has also been impaired due to the use of the stream for irrigation and the consequent exposure of large volumes of water to rapid evaporation. During 1920 the river was so low that sewage from the city, discharged below the water works intake backed up at high tide as far as the intake. The danger from such sewage contamination was minimized to some extent by operating the pumps at such time of tides so as to obtain water not affected by the tide-carried sewage from the city. A filtration plant for additional protection to the supply is to be built.—*E. S. Chase.*

Pipe Extension Charges. NICHOLAS S. HILL, JR. *Jour. New England Water Works Assoc.* 35, 2, June, 1921. This paper of Mr. Hill's deals with the

problem of making fair charges for pipe line extensions. In brief he states that the charge which must be made for pipe extensions so that a waterworks may be reasonably reimbursed will equal a fair return, interest, taxes and the cost of maintenance of the extension proper.

(b) The extension's proportion of the gross fixed service or static fixed charges on the entire plant. The proportion of the gross fixed charges of the entire plant chargeable to fixed service or static cost, varies from 30 per cent to 50 per cent of the fair return, taxes and depreciation on the entire plant.

(c) The extension's fair proportion of the fixed service or static operating expenses of the entire plant. The operating expenses chargeable to fixed service or static costs, vary from 15 per cent to 40 per cent of the operating cost of the entire plant.

The rule for determining the proper charge for an extension is stated by Mr. Hill as follows:

1. Ascertain the cost of the extension.
2. Determine the annual cost of the extension, including:
 - (a) Fair return on the cost of the extension.
 - (b) Taxes on the extension.
 - (c) Depreciation on the extension.
 - (d) Maintenance on the extension.
3. Take from 20 per cent to 40 per cent of the gross cost of service (gross cost of service equals fair return, taxes, depreciation, reserve, and operating expenses) as the proper portion chargeable to fixed service or static costs.
4. Divide the total fixed service or static cost by the number of inch-feet in the distribution system to determine the proper fixed service or static charge per inch-foot of main.
5. Multiply the number of inch-feet in the proposed extension by the fixed service or static charge per inch-foot as determined to ascertain the fair proportion of fixed service or static costs which should be allocated to the extension.
6. Add the fixed service or static charge for the extension to the costs chargeable to the extension proper to obtain the total annual costs chargeable to the extension.

Mr. Hill also discusses the various ways in which the consumer may pay for the cost of the extension. Among the various ways in which the consumer may pay the costs are the installment plan, the entire cost on the first payment, the deposit of a sum equal to the estimated annual charges for a ten-year period, and a guaranty of revenue to meet the annual charges on the extension. Mr. Hill also takes up the matter of deduction from the charges due to revenues from fire protection service. In the discussion of this paper the methods employed in various of the New England cities were brought out.—*E. S. Chase.*

Relations between Plumbers and Water Works Superintendents. J. WILBUR THOMPSON. *Jour. N. E. W. W. A.* 35, 2, June, 1921. This paper comprises a general discussion of the advance in standards of sanitation and plumbing, with some reference to the effect of different waters upon water pipes in residences. Following the paper is a discussion of pressure and temperature relief valves on hot water piping, and the danger of explosion resulting from overheating of hot water boilers is pointed out.—*E. S. Chase.*

Need of Uniformity in Plumbing Regulations. GEORGE C. WHIPPLE. Jour. N. E. W. W. A. 35, 2, June, 1921. This paper deals in a general way with the need for uniform plumbing regulations. He proposes minimum requirements of universal application, and rules and regulations to be adopted in whole or in part by local authorities.—*E. S. Chase.*

Water Distribution in Connection with Plumbing and the Action of Water on Metal. DAVID A. HEFFERNAN. Jour. N. E. W. W. A. 35, 2, June, 1921. A brief account of some trouble with stoppages in lead service pipe at Holyoke, Mass.—*E. S. Chase.*

Discussion of R. S. Weston's Paper. GEO. C. BUNKER. Lead Poisoning by Water. Jour. N. E. W. W. A. 35, 2, June, 1921. This discussion gives an account of experiments carried out in 1918 and 1919 upon the solvent action upon lead pipe of the water supply of Gatun, Canal Zone. This water supply of Gatun is supplied by impounding the run-off from a watershed of 1,119 acres. It is treated with sulphate of alumina, aerated, passed through sedimentation basins, treated with lime, filtered through rapid sand filters and disinfected with liquid chlorine. The chemical characteristics of the water are quite variable. In particular the alkalinity ranged in a period of 5 years from 13 to 21 p.p.m. and the soap hardness from 6.3 to 26 p.p.m., while the color ranged from 10 to 152 p.p.m. Lime had been used since 1916 in order to take care of alum used for the decolorization of the supply. It was not found feasible to neutralize, however, all free CO_2 by soda ash.

In order to determine the action of the filtered water upon lead, a piece of new 1-inch lead pipe, 25 feet in length was so connected that the filtered water ran through it at a rate of approximately 1 gallon per minute for nine hours and remained without circulation for the remainder of each day. The experiment extended from February, 1918, to August 10, 1919. Samples at ten days intervals were collected, of water standing over night, and of the running water. During the first ten days lead was determined daily and in the over-night samples the lead increased from 0.15 p.p.m. in the first sample to 0.65 p.p.m. in the fourth, and decreased to 0.50 p.p.m. in the tenth. In the running samples the lead increased from 0.13 p.p.m. on the first day to 0.37 p.p.m. on the fourth, and decreased to 0.12 p.p.m. on the tenth. Of subsequent samples the lead content in over-night samples ranged from a minimum of 0.7 p.p.m. to a maximum of 1.20 p.p.m., while in the running samples, the lead content ranged from 0.7 p.p.m. to a maximum of 1.10 p.p.m.

At the end of the experiment the interior of the pipe was examined and found to contain a very thin light coating, too thin to prevent continued action of water upon the lead pipe.

Aeration would increase the dissolved oxygen content, and, in Mr. Bunker's opinion, increases the corrosive action of water on lead pipe, and although free carbonic acid was removed from water passing through the pipe corrosive action was not stopped. Mr. Bunker attributes this fact to the low hardness and alkalinity, rather than to the rather high dissolved oxygen content, which overcame the restraining effect of hydroxyl ions, lime being applied in amount ranging from about 30 to 60 pounds per million gallons.

Mr. Bunker made another experiment by exposing small pieces of sheet lead to the action of different waters for periods of one and seven days. The

results of these experiments are given in condensed form in a table in his paper. In the case of the Agua Clara supply it was found that a carbonate alkalinity of 2.4 p. p. m. produced by the addition of lime must be maintained in order to keep the lead content of water used in the houses below 0.1 p. p. m. In these experiments the greatest action was shown by neutral distilled water which dissolved 185 p.p.m. in one day and 500 p.p.m. in seven days. Water from the Agua Clara supply which had been settled but to which no lime had been added, dissolved 5.0 p.p.m. one day and 9.5 p.p.m. in seven days. Although no ill effects have been recognized by Mr. Bunker in the use of the Canal waters, it is his opinion that the installation of lead services in the Gatun District should be discontinued. Traces of residual chlorine did not increase lead solvency. Mr. Bunker suggests that dissolved lead in water supplied to houses may be of greater public health significance than has been generally appreciated.—*E. S. Chase.*

The Flush Valve. GORDON M. FAIR. *Jour. N. E. W. W. A.* 35, 2, June, 1921. This paper deals with the sanitary, economic and hydraulic factors in connection with the use of automatic quick opening and slow closing flush valves. The results of tests of rate of discharge and quantities discharged, together with observations as to water hammer, with several types of flush valves, are given in detail and discussed. The conclusions arrived at are as follows:

1. Unless carefully placed in a well-designed distributing system the use of the flush valve may result in contamination of the water supply,
2. There is little reason to believe that water will be conserved by the use of the flush valve,
3. The installing of flush valves is only economical in large buildings,
4. The effect of the use of the flush valves on water metering and water hammer, needs investigation,
5. The choice of the type of distributing system should be made only after the type of flush valve that will be used, has been determined.—*E. S. Chase.*

Report of Committee on Rainfall and Run-off Measurements. ROBERT E. HORTON, CHAIRMAN. *Jour. N. E. W. W. A.* 35, 2, June, 1921. This report brings down to date the records of previously published rainfall and run-off data of New England drainage areas, together with additional records of the yields of similar water works drainage areas in New England and New York. The data are accompanied by information regarding matters affecting the accuracy of the records and the yield of the basins. No attempt is made by the committee to analyze or make deductions from these records. The report recommends that the water works superintendents throughout New England maintain at least one rain gage and that where maintained daily records of run-off and precipitation be published each year.

References are also given to records of evaporation from water surfaces.

In the discussion of this report the question was raised as to the effect of different kinds and intensities of vegetation upon watershed evaporation and yields.—*E. S. Chase.*

Cast Iron Pipe, the Method of Manufacture and its Inspection: WM. R. CONARD. *Jour. N. E. W. W. A.* 35, 3, September, 1921. Description of manufacture and inspection of cast iron pipe. Deals with requirements of the

iron, the making of the mold, casting, cleaning, coating and testing of cast iron pipe. The desirability of research work relative to the best type of pipe coating is emphasized in the paper itself and in the discussion of the paper.—*E. S. Chase.*

Rainfall in New England. X. H. GOODNOUGH Jour. N. E. W. W. A. 35, 3, September 1921. This paper presents tabulation of rainfall records in New England together with similar records for stations in adjacent parts of New York and Canada for the years 1913 to 1920 inclusive, these records being a continuation of records given in a previous paper published by Mr. Goodnough in the Journal of New England Water Works for September 1915. The records of many new stations which have been established subsequent to the earlier paper are given as well as a few long records of observation not previously published.

Mr. Goodnough states that from inspection of a large number of rain gages, the standard 8-inch rain gage properly cared for appears to furnish the most reliable observations. The difficulty of measuring snowfall in any way is pointed out.—*E. S. Chase.*

Argument Against Boating and Fishing in Water Supply Reservoirs. Jour. N. E. W. W. 35, 3, September, 1921. A letter sent to the Governor of Massachusetts by the officers and past presidents of the New England Water Works Association requesting him to veto a bill which would have allowed boating and fishing in Lake Cochituate, a reservoir of the Metropolitan Water Works System.—*E. S. Chase.*

New Mobile Water Purification Unit. Eng. & Cont. 56, 6. [cf. Military Engineer, July-August 1921.] August 10, 1921. This article describes a water purification unit of the type used by the U. S. Army for supplying pure drinking water to mobile forces in the field. This outfit was developed by the office of the Chief of Engineers in collaboration with Wallace Tiernan Co. Inc. of New York.

This equipment is mounted on a 3½ ton Class B. Army truck. It consists essentially of a single centrifugal pump delivering one hundred gallons per minute against a 75 foot head at 1150 r. p. m. A direct connected 4 cylinder gasoline engine delivering about 25 H. P. at 1150 r. p. m.; a 42-inch pressure mechanical filter with a hand agitator, a 5-way control valve, a combination direct dry feed and solution feed chlorinator, with a capacity of 1½ to 12 pounds of chlorine per 24 hours, an alum pot and a soda ash tank with appropriate feeds, a venturi meter and a water meter, and a simple laboratory for making acidity, alkalinity, color, turbidity and free chlorine tests.—*E. S. Chase.*

Notes on Water Filtration. GEORGE MITCHEL. Eng. & Cont. 56, 9, August 31, 1921. [cf. Proc. Inst. Wat. Eng. London 1920] Mr. Mitchell states that any water can be successfully treated by mechanical filters without coagulation, provided chlorination follows. These filters are of value prior to slow sand filtration. An experiment with preliminary filtering through rapid sand filters of a relatively clear raw water, as at Aberdeen, show that a slow sand filter treating prefiltered water passed 1,530,000,000 gallons per acre without requiring cleaning. Compared with the necessity of sixteen cleanings of a check filter treating the same amount of water without prefilter-

ing. Higher rates of slow sand filtration are feasible, as is shown by the fact that at Aberdeen the average rate of filtration has been 3,500,000 gallons per acre per day, which, however, at times has been exceeded. The bacteriological results have invariably shown the absence of *B. coli* in 100 cc. inoculation, and in a 13 months' period not a case of typhoid fever occurred in a population of 170,000 supplied by the water.

In resanding the author thoroughly rakes the old sand with long-toothed rakes, putting on washed sand and finishing up with 1 inch of old sand.

A system of cleaning devised by Mr. Caink of Worcester, England, is as follows: The water having been lowered to about sand level, the mud is squeegeed off with the assistance of a stream of water, the muddy water being removed by a channel sunk in the sand. There after the water is lowered about a foot, and a light harrow is passed over the sand, which is at the same time rolled. The filter is then ready for use again. This is repeated for a long period—in some cases over two years—when a thickness of about 4 inches of dirtiest sand is removed, washed and restored to the filter.

This method of cleaning is supposed to have the advantage of providing a comparatively thick film of fresh sand and a correspondingly greater efficiency. The thickness of the sand remains constant and there is a large economy in working expenses and a considerable increase in output per unit of area.—*E. S. Chase.*

Wells and Ground Water. Eng. & Cont. 56, 9, August 31, 1921. [cf. Engineering, London.] Percolation of the supply to the ground water depends on the rainfall, porosity of strata pierced through and extent of exposed surface. It varies inversely with the soil evaporation; is greatest in winter and during heavy long-continued rains; it is least in summer with short showers of rain. The deficiency of ground water will be felt most towards the close of a long dry season where the reserve of water furnished by the rains of the preceding rainy season have been reduced to their lowest limit, by the demands of the dry months. A failure of rain, or scanty rainfall during the rainy season is therefore more likely to cause a diminution of ground water, or a drought, than a long dry summer.

This article also gives certain data regarding the influence of depth of ground water on soil evaporation, and the results of various experiments on percolation and soil evaporation.—*E. S. Chase.*

Cavity Wells in India. Eng. & Cont. 56, 9, August 31, 1921. [cf. Engineering, London.] A description of a method employed in increasing the yield of wells by producing cavities in the water-bearing stratum at the bottom of the bore pipe, a method used in India with considerable success.—*E. S. Chase.*

Water Filtration in Madras. JAMES MADELEY. Eng. & Cont. 56, 9, August 31, 1921. [cf. Proc. Inst. Wat. Eng. London, 1920.] This article gives the results of operation of slow sand filters in tropical countries. The results of operation of slow sand filters are not so good under tropical conditions as would be expected in England. The deterioration in the results in Madras are attributed by Mr. Madeley to the breaking off of the filtering skin probably by frogs, crabs, fish and heavy rains, and by algae masses which break away and carry off portions of the filtering skin. Remedial measures consisting of

guard walls, fine wire screens on filter inlets, and the maintenance of $3\frac{1}{2}$ to 4 feet of water upon these filters, were fairly efficacious. Covering of the filters was thought beneficial providing a sufficient depth of water over the surface of the sand was maintained.

Experiments on the effect of storage and sunlight upon the bacterial content showed a marked decrease in bacteria during the first four days, with a maximum reduction being reached about the eighth day. No consistent advantage was shown by combined sunlight and storage over storage alone.

Mr. Madeley has decided that chlorination should be used to supplement filtration and proposes to increase the rate of filtration and supplement with chlorination.—*E. S. Chase.*

Electrically-Operated Valves at Buffalo, N. Y., Eng. & Cont. 56, 11, September 14, 1921. A description of the methods of electrical operation and control of large gate valves on the discharge line of the Buffalo pumping station. In order that the opening and closing of these valves for the most advantageous operation of the various pumping stations may be done at nominal expense.—*E. S. Chase.*

Some Problems Encountered by the Waterworks Engineer. W. C. HAWLEY. Eng. & Cont. 56, 11, September 14, 1921. An account of experiences with unusual problems dealt with in the operation of waterworks, including the emergency repair of a standpipe, the operation of an old plant while building a new one, and experience with earth slips.—*E. S. Chase.*

Apparatus and Chemicals for a Small Water Works Lab. Eng. & Cont. 56, 11, September 14, 1921. [cf. Bull. No. 16 Ill. State Water Survey Div.] This article gives a list of apparatus, chemicals and supplies recommended by the Illinois State Water Survey for the equipment of small water works laboratories in order to make the examinations described in Standard Methods of Water Analysis of the American Public Health Association.—*E. S. Chase.*

Underdrainage for Preventing Alkali Action on Winnipeg Aqueduct. Contract Record. August 17, 1921. An account of the methods employed to underdrain a section of the 8-foot reinforced concrete aqueduct of the greater Winnipeg water district in order to remove alkali drainage water which was found to be causing serious disintegration of the concrete.—*E. S. Chase.*

Prices of Waterworks and other Materials, Month by Month. Eng. & Cont. 56, 15, Oct. 12, 1921. A series of diagrams and tables of prices of various engineering materials, compiled in the office of Dabney H. Maury, consulting engineer, Chicago, Ill.—*E. S. Chase.*

Methods and Cost of Jacketing Steel Pipe Line with Reinforced Concrete. Eng. & Cont. 56, 15, October 12, 1921. [cf. Concrete, September, 1921.] This comprises a description of the successful use of reinforced concrete for jacketing the Dominguez Water Company, Los Angeles, California, for the protection of a steel pipe subject to the corrosion of an alkali soil. At the time the article was written some 6500 feet of 33-inch steel pipe had been protected by the reinforced concrete, at an average total cost per foot of \$2.01.—*E. S. Chase.*

Handling Liquid Chlorine. D. K. BARTLETT. Eng. and Cont. 56, 19, November 9, 1921. The increased use of chlorine gas for the textile and various other industries, and for public water supply systems, has resulted

in the storing of chlorine in from 4000 to 5000 different points throughout the country, in quantities of from a few cylinders to many thousand pounds. The method of this storage of chlorine has been taken up very carefully by Mr. Bartlett in this paper. He points out that the escape of gas from a container may be due to either a true explosion, an increase of pressure due to heat, or to leaks, and if the gas escapes from the container the resulting danger may be due to inflammability, poisonous effects or to irritating effects upon the respiratory system. In the case of chlorine the danger of a true explosion is non-existent due to the fact that it is a non-explosive gas. Furthermore, the rupture of a cylinder resulting from a change or increase in temperature, is very slight. All cylinders and other containers are provided with fusible plugs which melt at 158° F., at which temperature the pressure is about one-half the test pressure of the drums at the time of manufacture, and a quarter of the pressure of the small cylinders. There has never been an instance of the bursting of a container in transit, or in user's plant.

In a few cases of fire where large quantities of chlorine have been in storage the upward draft due to the heat has been sufficient to carry the gas upward and cause a sufficient dilution so the the fire fighters were caused no inconvenience.

In the case of leaks the odor of the chlorine affords its own danger signal, so that reasonable care will prevent extensive trouble arising from leaks.

This paper continues with general and specific directions relative to the detection and elimination of sources of leakage, and describes first aid measures in the case of persons overcome by the gas.

The best methods for the shipment of chlorine in large quantities and for its storage after receipt are also discussed in this article.—*E. S. Chase.*